

## CYCLOPROPYL $\beta$ -AMINO ACID DERIVATIVES

This application claims priority from U.S. Provisional Application 60/441,825 filed January 22, 2003; the entire contents of which are hereby incorporated herein by reference.

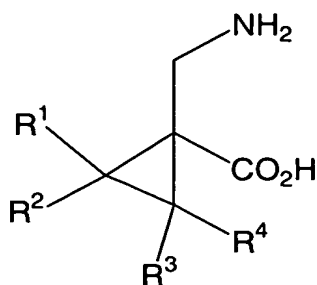
### BACKGROUND OF THE INVENTION

This invention relates to novel cyclopropyl  $\beta$ -amino acids derivatives, pharmaceutical compositions containing them and their use for the treatment of various central nervous system and other disorders. The cyclopropyl  $\beta$ -amino acids derivatives of this invention exhibit activity as  $\alpha 2\delta$  ligands ( $\alpha 2\delta$  ligand). Such compounds have affinity for the  $\alpha 2\delta$  subunit of a calcium channel. Such compounds have also been referred to in the literature as gamma-aminobutyric acid (GABA) analogs.

Several  $\alpha 2\delta$  ligands are known. Gabapentin, a cyclic  $\alpha 2\delta$  ligand, is now commercially available (Neurontin®, Warner-Lambert Company) and extensively used clinically for treatment of epilepsy and neuropathic pain. Such cyclic  $\alpha 2\delta$  ligands are described in US Patent No. 4,024,175, which issued on May 17, 1977, and US Patent No. 4,087,544, which issued on May 2, 1978. Other series of  $\alpha 2\delta$  ligands are described in US Patent No. 5,563,175, which issued on October 8, 1996, US Patent No. 6,316,638, which issued on November 13, 2001, US Provisional Patent Application 60/353,632, which was filed on January 31, 2002, European Patent Application EP 1112253, which was published on July 4, 2001, PCT Patent Application WO 99/08671, which was published on February 25, 1999, and PCT Patent Application WO 99/61424, which was published on December 2, 1999. These patents and applications are incorporated herein by reference in their entireties.

### SUMMARY OF THE INVENTION

This invention relates to cyclopropyl- $\beta$ -amino acids derivatives of the formula I



I

wherein  $R^1$  and  $R^2$  are selected, independently, from hydrogen, ( $C_1$ – $C_{10}$ )straight or branched alkyl, ( $C_1$ – $C_{10}$ )straight or branched alkoxyalkyl, phenyl-( $C_1$ – $C_3$ )straight or branched alkyl and phenyl-( $C_1$ – $C_3$ )straight or branched alkoxyalkyl, wherein said phenyl moieties can optionally be substituted with one or two substituents selected, independently, from halo or ( $C_1$ – $C_3$ )alkyl;

or  $R^1$  and  $R^2$ , together with the carbon to which they are attached, form a cyclopentyl, cyclohexyl or cycloheptyl ring which can optionally be substituted with one or two substituents selected, independently, from the group of substituents named in the definition of  $R^1$  and  $R^2$  above; and

$R^3$  and  $R^4$  are selected, independently, from hydrogen and methyl;  
and the pharmaceutically acceptable salts of such compounds.

Preferred embodiments of this invention include the following compounds and their pharmaceutically acceptable salts:

- 1-Aminomethyl-spiro[2.4]heptane-1-carboxylic acid;
- 1-Aminomethyl-spiro[2.5]octane-1-carboxylic acid;
- 1-Aminomethyl-spiro[2.6]nonane-1-carboxylic acid;
- 1-Aminomethyl-5-methyl-spiro[2.4]heptane-1-carboxylic acid;
- 1-Aminomethyl-2-methyl-spiro[2.6]nonane-1-carboxylic acid;
- 1-Aminomethyl-2,2-dimethyl-cyclopropanecarboxylic acid;
- 1-Aminomethyl-2,2-di-n-propyl-cyclopropanecarboxylic acid;
- 1-Aminomethyl-2-isopropyl-cyclopropanecarboxylic acid;
- 1-Aminomethyl-2-cyclopropyl-cyclopropanecarboxylic acid;
- 1-Aminomethyl-2-isobutyl-cyclopropanecarboxylic acid;
- 1-Aminomethyl-2-(1-ethyl-propyl)-cyclopropanecarboxylic acid;

1-Aminomethyl-2-cyclohexyl-cyclopropanecarboxylic acid; and  
1-Aminomethyl-2-(2-phenethyl)-cyclopropanecarboxylic acid.

Examples of specific embodiments of this invention are the following compounds and their pharmaceutically acceptable salts:

1-Aminomethyl-spiro[2.3]hexane-1-carboxylic acid;  
1-Aminomethyl-spiro[2.7]decane-1-carboxylic acid;  
1-Aminomethyl-5,6-dimethyl-spiro[2.4]heptane-1-carboxylic acid;  
1-Aminomethyl-5-methyl-spiro[2.5]octane-1-carboxylic acid;  
1-Aminomethyl-5,7-dimethyl-spiro[2.5]octane-1-carboxylic acid;  
1-Aminomethyl-2,2-dimethyl-spiro[2.6]nonane-1-carboxylic acid;  
1-Aminomethyl-2,2-diethyl-cyclopropanecarboxylic acid;  
1-Aminomethyl-2,2-di-n-butyl-cyclopropanecarboxylic acid;  
1-Aminomethyl-2,2-diisobutyl-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-n-propyl-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(2-methyl-butyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(2,2-dimethyl-butyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(2-methyl-pentyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(2,2-dimethyl-pentyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(3-ethyl-pentyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(4-ethyl-hexyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(1-methyl-cyclopropylmethyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(1-ethyl-cyclopropylmethyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(1-propyl-cyclopropylmethyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(2-methyl-hexyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(2,2-dimethyl-hexyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(2,6-dimethyl-heptyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(3,7-dimethyl-octyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-n-butyl-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-cyclobutyl-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-cyclopentyl-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-cycloheptyl-cyclopropanecarboxylic acid;

1-Aminomethyl-2-cyclopropylmethyl-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-cyclohexylmethyl-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(2-cyclohexyl-ethyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-phenyl-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-benzyl-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(2-fluoro-phenyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(3-fluoro-phenyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(4-fluoro-phenyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(2,3-difluoro-phenyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(2,4-difluoro-phenyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(2,5-difluoro-phenyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(2,6-difluoro-phenyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(3,5-difluoro-phenyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(2-fluoro-benzyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(3-fluoro-benzyl)-cyclopropanecarboxylic acid  
1-Aminomethyl-2-(4-fluoro-benzyl)-cyclopropanecarboxylic acid  
1-Aminomethyl-2-(2,3-difluoro-benzyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(2,4-difluoro-benzyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(2,5-difluoro-benzyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(2,6-difluoro-benzyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-(3,5-difluoro-benzyl)-cyclopropanecarboxylic acid;  
1-Aminomethyl-2-[2-(2-fluoro-phenyl)-ethyl]-cyclopropanecarboxylic  
acid;  
1-Aminomethyl-2-[2-(3-fluoro-phenyl)-ethyl]-cyclopropanecarboxylic  
acid;  
1-Aminomethyl-2-[2-(4-fluoro-phenyl)-ethyl]-cyclopropanecarboxylic  
acid;  
1-Aminomethyl-2-[2-(2,3-difluoro-phenyl)-ethyl]-cyclopropanecarboxylic  
acid;  
1-Aminomethyl-2-[2-(2,4-difluoro-phenyl)-ethyl]-cyclopropanecarboxylic  
acid;  
1-Aminomethyl-2-[2-(2,5-difluoro-phenyl)-ethyl]-cyclopropanecarboxylic  
acid;

1-Aminomethyl-2-[2-(2,6-difluoro-phenyl)-ethyl]-cyclopropanecarboxylic acid;

1-Aminomethyl-2-[2-(3,5-difluoro-phenyl)-ethyl]-cyclopropanecarboxylic acid;

1-Aminomethyl-2-methoxymethyl-cyclopropanecarboxylic acid;

1-Aminomethyl-2-phenoxyethyl-cyclopropanecarboxylic acid;

1-Aminomethyl-2-benzyloxymethyl-cyclopropanecarboxylic acid;

1-Aminomethyl-2-(2-methoxy-ethyl)-cyclopropanecarboxylic acid;

1-Aminomethyl-2-(2-phenoxy-ethyl)-cyclopropanecarboxylic acid;

1-Aminomethyl-2-(2-benzyloxy-ethyl)-cyclopropanecarboxylic acid;

1-Aminomethyl-2-(3-methoxy-propyl)-cyclopropanecarboxylic acid;

1-Aminomethyl-2-(3-phenoxy-propyl)-cyclopropanecarboxylic acid;

1-Aminomethyl-2-(3-benzyloxy-propyl)-cyclopropanecarboxylic acid;

1-Aminomethyl-2,2-bis-methoxymethyl-cyclopropanecarboxylic acid;

1-Aminomethyl-2,2-bis-phenoxyethyl-cyclopropanecarboxylic acid;

1-Aminomethyl-2,2-bis-benzyloxymethyl-cyclopropanecarboxylic acid;

1-Aminomethyl-2,2-bis-(2-methoxy-ethyl)-cyclopropanecarboxylic acid;

1-Aminomethyl-2,2-bis-(2-phenoxy-ethyl)-cyclopropanecarboxylic acid;

1-Aminomethyl-2,2-bis-(2-benzyloxy-ethyl)-cyclopropanecarboxylic

acid;

1-Aminomethyl-2,2-bis-(3-methoxy-propyl)-cyclopropanecarboxylic

acid;

1-Aminomethyl-2,2-bis-(3-phenoxy-propyl)-cyclopropanecarboxylic

acid; and

1-Aminomethyl-2,2-bis-(3-benzyloxy-propyl)-cyclopropanecarboxylic

acid.

The phrase "lower alkyl", as used herein, unless otherwise indicated, means a straight or branched alkyl group or radical having from 1 to 6 carbon atoms, and includes methyl, ethyl, *n*-propyl, *i*-propyl, *n*-butyl, *i*-butyl, *sec*-butyl, *tert*-butyl, *n*-pentyl, *n*-hexyl, and the like.

The term "alkyl", as used herein, unless otherwise indicated, includes saturated monovalent hydrocarbon radicals having straight, branched or cyclic moieties or combinations thereof. Examples of "alkyl" groups include, but are not limited to, methyl, ethyl, propyl, isopropyl, butyl, iso- sec- and tert-butyl,

pentyl, hexyl, heptyl, 3-ethylbutyl, cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl, norbornyl, and the like.

The term “cycloalkyl”, unless otherwise stated, means saturated monovalent carbocyclic groups containing from 3 to 8 carbons and are selected from cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl, and cyclooctyl.

The term “alkoxy”, as used herein, unless otherwise indicated, means “alkyl-O-”, wherein “alkyl” is as defined above. Examples of “alkoxy” groups include, but are not limited to, methoxy, ethoxy, propoxy, butoxy and pentoxy.

The term “one or more substituents”, as used herein, refers to a number of substituents that equals from one to the maximum number of substituents possible based on the number of available bonding sites.

The terms “halo” and “halogen”, as used herein, unless otherwise indicated, include, fluoro, chloro, bromo and iodo.

Compounds of the formula I may contain chiral centers and therefore may exist in different enantiomeric and diastereomeric forms. Individual isomers can be obtained by known methods, such as optical resolution, optically selective reaction, or chromatographic separation in the preparation of the final product or its intermediate. This invention relates to all optical isomers and all stereoisomers of compounds of the formula I, both as racemic mixtures and as individual enantiomers and diastereoisomers of such compounds, and mixtures thereof, and to all pharmaceutical compositions and methods of treatment defined above that contain or employ them, respectively. Individual enantiomers of the compounds of formula I may have advantages, as compared with the racemic mixtures of these compounds, in the treatment of various disorders or conditions.

In so far as the compounds of formula I of this invention are basic compounds, they are capable of forming a wide variety of different salts with various inorganic and organic acids. Although such salts must be pharmaceutically acceptable for administration to animals, it is often desirable in practice to initially isolate the base compound from the reaction mixture as a pharmaceutically unacceptable salt and then simply convert to the free base compound by treatment with an alkaline reagent and thereafter convert the free base to a pharmaceutically acceptable acid addition salt. The free base

form of the compound may be regenerated by contacting the acid addition salt so formed with a base, and isolating the free base form of the compound in the conventional manner. The free base forms of compounds prepared according to a process of the present invention differ from their respective acid addition salt forms somewhat in certain physical properties such as solubility, crystal structure, hygroscopicity, and the like, but otherwise free base forms of the compounds and their respective acid addition salt forms are equivalent for purposes of the present invention.

Pharmaceutically acceptable acid addition salts of the basic compounds useful in the method of the present invention include nontoxic salts derived from inorganic acids such as hydrochloric, nitric, phosphoric, sulfuric, hydrobromic, hydroiodic, hydrofluoric, phosphorous, and the like, as well nontoxic salts derived from organic acids, such as aliphatic mono- and dicarboxylic acids, phenyl-substituted alkanoic acids, hydroxy alkanoic acids, alkanedioic acids, aromatic acids, aliphatic and aromatic sulfonic acids, etc. Such salts thus include sulfate, pyrosulfate, bisulfate, sulfite, bisulfite, nitrate, phosphate, monohydrogenphosphate, dihydrogenphosphate, metaphosphate, pyrophosphate, chloride, bromide, iodide, acetate, trifluoroacetate, propionate, caprylate, isobutyrate, oxalate, malonate, succinate, suberate, sebacate, fumarate, maleate, mandelate, benzoate, chlorobenzoate, methylbenzoate, dinitrobenzoate, phthalate, benzenesulfonate, toluenesulfonate, phenylacetate, citrate, lactate, malate, tartrate, methanesulfonate, and the like. Also contemplated are salts of amino acids such as arginate and the like and gluconate, galacturonate (see, for example, Berge S.M. et al., "Pharmaceutical Salts," *J. of Pharma. Sci.*, 1977;66:1).

In so far as the compounds of formula I of this invention are acidic compounds, they are all capable of forming a wide variety of different salts with various inorganic and organic bases. A pharmaceutically acceptable base addition salt of an acidic compound useful in the method of the present invention may be prepared by contacting the free acid form of the compound with a nontoxic metal cation such as an alkali or alkaline earth metal cation, or an amine, especially an organic amine. Examples of suitable metal cations include sodium cation ( $\text{Na}^+$ ), potassium cation ( $\text{K}^+$ ), magnesium cation

(Mg<sup>2+</sup>), calcium cation (Ca<sup>2+</sup>), and the like. Examples of suitable amines are N,N'-dibenzylethylenediamine, chloroprocaine, choline, diethanolamine, dicyclohexylamine, ethylenediamine, N-methylglucamine, and procaine (see, for example, Berge, *supra.*, 1977). A base addition salt of an acidic compound useful in the method of the present invention may be prepared by contacting the free acid form of the compound with a sufficient amount of a desired base to produce the salt in the conventional manner. The free acid form of the compound may be regenerated by contacting the salt form so formed with an acid, and isolating the free acid of the compound in the conventional manner. The free acid forms of the compounds useful in the method of the present invention differ from their respective salt forms somewhat in certain physical properties such as solubility, crystal structure, hygroscopicity, and the like, but otherwise the salts are equivalent to their respective free acid for purposes of the present invention.

The present invention also includes isotopically labelled compounds, which are identical to those recited in formula I, but for the fact that one or more atoms are replaced by an atom having an atomic mass or mass number different from the atomic mass or mass number usually found in nature. Examples of isotopes that can be incorporated into compounds of the present invention include isotopes of hydrogen, carbon, nitrogen, oxygen, phosphorous, sulfur, fluorine and chlorine, such as <sup>2</sup>H, <sup>3</sup>H, <sup>13</sup>C, <sup>11</sup>C, <sup>14</sup>C, <sup>15</sup>N, <sup>18</sup>O, <sup>17</sup>O, <sup>31</sup>P, <sup>32</sup>P, <sup>35</sup>S, <sup>18</sup>F, and <sup>36</sup>Cl, respectively. Compounds of the present invention, prodrugs thereof, and pharmaceutically acceptable salts of said compounds or of said prodrugs which contain the aforementioned isotopes and/or other isotopes of other atoms are within the scope of this invention. Certain isotopically labelled compounds of the present invention, for example those into which radioactive isotopes such as <sup>3</sup>H and <sup>14</sup>C are incorporated, are useful in drug and/or substrate tissue distribution assays. Tritiated, *i.e.*, <sup>3</sup>H, and carbon-14, *i.e.*, <sup>14</sup>C, isotopes are particularly preferred for their ease of preparation and detectability. Further, substitution with heavier isotopes such as deuterium, *i.e.*, <sup>2</sup>H, can afford certain therapeutic advantages resulting from greater metabolic stability, for example increased *in vivo* half-



life or reduced dosage requirements and, hence, may be preferred in some circumstances.

Certain of the compounds useful in the method of the present invention can exist in unsolvated forms as well as solvated forms, including hydrated forms. In general, the solvated forms, including hydrated forms, are equivalent to unsolvated forms and are intended to be encompassed within the scope of the present invention.

The effectiveness of an orally administered drug is dependent upon the drug's efficient transport across the mucosal epithelium and its stability in entero-hepatic circulation. Drugs that are effective after parenteral administration but less effective orally, or whose plasma half-life is considered too short, may be chemically modified into a prodrug form.

A prodrug is a drug that has been chemically modified and may be biologically inactive at its site of action, but which may be degraded or modified by one or more enzymatic or other in vivo processes to the parent bioactive form.

This chemically modified drug, or prodrug, should have a different pharmacokinetic profile than the parent drug, enabling easier absorption across the mucosal epithelium, better salt formulation and/or solubility, improved systemic stability (for an increase in plasma half-life, for example). These chemical modifications may be, for example:

- 1) ester or amide derivatives which may be cleaved by, for example, esterases or lipases. For ester derivatives, the ester is derived from the carboxylic acid moiety of the drug molecule by known means. For amide derivatives, the amide may be derived from the carboxylic acid moiety or the amine moiety of the drug molecule by known means;
- 2) peptides which may be recognized by specific or nonspecific proteinases (A peptide may be coupled to the drug molecule via amide bond formation with the amine or carboxylic acid moiety of the drug molecule by known means);

- 3) derivatives that accumulate at a site of action through membrane selection of a prodrug form or modified prodrug form; or
- 4) any combination of 1 to 3.

Current research in animal experiments has shown that the oral absorption of certain drugs may be increased by the preparation of "soft" quaternary salts. The quaternary salt is termed a "soft" quaternary salt since, unlike normal quaternary salts, *e.g.*,  $R-N^+(CH_3)_3$ , it can release the active drug upon hydrolysis.

"Soft" quaternary salts have useful physical properties compared with the basic drug or its salts. Water solubility may be increased compared with other salts, such as the hydrochloride, but more important there may be an increased absorption of the drug from the intestine. Increased absorption is probably due to the fact that the "soft" quaternary salt has surfactant properties and is capable of forming micelles and unionized ion pairs with bile acids, etc., which are able to penetrate the intestinal epithelium more effectively. The prodrug, after absorption, is rapidly hydrolyzed with release of the active parent drug.

Prodrugs of compounds of formula I are included within the scope of this invention. Prodrugs and soft drugs are known in the art (Palomino E., *Drugs of the Future*, 1990;15(4):361-368). The last two citations are hereby incorporated by reference.

Certain of the compounds of the present invention can exist in unsolvated forms as well as solvated forms, including hydrated forms. In general, the solvated forms, including hydrated forms, are equivalent to unsolvated forms and are intended to be encompassed within the scope of the present invention.

This invention also relates to a pharmaceutical composition comprising a therapeutically effective amount of a compound of the formula I, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier.

This invention also relates to a method of treating a disorder or condition selected from faintness attacks, epilepsy, asphyxia, general anoxia, hypoxia, spinal cord trauma, traumatic brain injury, head trauma, cerebral ischemia, stroke (including thromboembolic stroke, focal ischemia, global ischemia, transient cerebral ischemia attacks and other cerebral vascular problems accompanied by cerebral ischemia such as in patients undergoing carotid endarterectomy or other vascular surgical procedures in general or diagnostic vascular surgical procedures such as angiography), cramp caused by thiosemicarbazide, cardiazole cramp, and cerebral vascular disorders due to acute or chronic cerebrovascular damage such as cerebral infarction, subarachnoid haemorrhage or cerebral oedema in a mammal, comprising administering to a mammal in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

This invention also relates to a method of treating a disorder or condition selected from the group consisting of neurocardiac disorders such as neurocardiac syncope, neurogenic syncope, hypersensitive Carotid sinus, neurovascular syndrome and arrhythmias including arrhythmias secondary to gastrointestinal disturbances in a mammal, comprising administering to a mammal in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

This invention also relates to a method of treating a disorder or condition selected from acute pain, chronic pain, pain resulting from soft tissue and peripheral damage such as acute trauma; postherpetic neuralgia, occipital neuralgia, trigeminal neuralgia, segmental or intercostal neuralgia and other neuralgias; pain associated with osteoarthritis and rheumatoid arthritis; musculo-skeletal pain such as pain associated with strains, sprains and trauma such as broken bones; spinal pain, central nervous system pain such as pain due to spinal cord or brain stem damage; lower back pain, sciatica, dental pain, myofascial pain syndromes, episiotomy pain, gout pain, and pain resulting from burns; deep and visceral pain, such as heart pain; muscle pain, eye pain, inflammatory pain, orofacial pain, for example, odontalgia; abdominal pain, and gynecological pain, for example, dysmenorrhoea, labour pain and pain associated with endometriosis;

somatogenic pain; pain associated with nerve and root damage, such as pain associated with peripheral nerve disorders, for example, nerve entrapment and brachial plexus avulsions; pain associated with limb amputation, tic douloureux, neuroma, or vasculitis; diabetic neuropathy, chemotherapy-induced-neuropathy, acute herpetic and postherpetic neuralgia; atypical facial pain, neuropathic lower back pain, and arachnoiditis, trigeminal neuralgia, occipital neuralgia, segmental or intercostal neuralgia, HIV related neuralgias and AIDS related neuralgias and other neuralgias; allodynia, hyperalgesia, burn pain, idiopathic pain, pain caused by chemotherapy; occipital neuralgia, psychogenic pain, brachial plexus avulsion, pain associated with restless legs syndrome; pain associated with gallstones; pain caused by chronic alcoholism or hypothyroidism or uremia or vitamin deficiencies; neuropathic and non-neuropathic pain associated with carcinoma, often referred to as cancer pain, phantom limb pain, functional abdominal pain, headache, including migraine with aura, migraine without aura and other vascular headaches, acute or chronic tension headache, sinus headache and cluster headache; temporomandibular pain and maxillary sinus pain; pain resulting from ankylosing spondylitis; pain caused by increased bladder contractions; post operative pain, scar pain, and chronic non-neuropathic pain such as pain associated with HIV, anthralgia, vasculitis and fibromyalgia in a mammal, comprising administering to a mammal in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

This invention also relates to a method of treating a disorder or condition selected from mood disorders, such as depression, or more particularly, depressive disorders, for example, major depressive disorder, severe unipolar recurrent major depressive episodes, dysthymic disorder, depressive neurosis and neurotic depression, melancholic depression including anorexia, weight loss, insomnia, early morning waking or psychomotor retardation, atypical depression (or reactive depression) including increased appetite, hypersomnia, psychomotor agitation or irritability; treatment resistant depression; seasonal affective disorder and pediatric depression; premenstrual syndrome, premenstrual dysphoric disorder, hot flashes, bipolar disorders or manic depression, for example,

bipolar I disorder, bipolar II disorder and cyclothymic disorder; seasonal affective disorder, conduct disorder and disruptive behavior disorder; stress related somatic disorders and anxiety disorders, such as childhood anxiety disorder, panic disorder with or without agoraphobia, agoraphobia without history of panic disorder, specific phobias (*e.g.*, specific animal phobias), social anxiety disorder, social phobia, obsessive-compulsive disorder, stress disorders including post-traumatic stress disorder and acute stress disorder, and generalized anxiety disorder in a mammal, comprising administering to a mammal in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

This invention also relates to a method of treating a disorder or condition selected from the group consisting of borderline personality disorder; schizophrenia and other psychotic disorders, for example, schizophreniform disorders, schizoaffective disorders, delusional disorders, brief psychotic disorders, shared psychotic disorders, psychotic disorders due to a general medical condition, psychotic disorders with delusions or hallucinations, substance induced psychotic disorder, psychotic episodes of anxiety, anxiety associated with psychosis, psychotic mood disorders such as severe major depressive disorder; mood disorders associated with psychotic disorders such as acute mania and depression associated with bipolar disorder, mood disorders associated with schizophrenia; and behavioral disturbances associated with mental retardation in a mammal, comprising administering to a mammal in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

This invention also relates to a method of treating a disorder or condition selected from the group consisting of sleep disorders such as insomnia (*e.g.*, primary insomnia including psychophysiological and idiopathic insomnia, secondary insomnia including insomnia secondary to restless legs syndrome, Parkinson's disease or another chronic disorder, and transient insomnia), somnambulism, sleep deprivation, REM sleep disorders, sleep apnea, hypersomnia, parasomnias, sleep-wake cycle disorders, jet lag, narcolepsy, sleep disorders associated with shift work or irregular work schedules, deficient sleep quality due to a decrease in slow wave sleep caused

by medications or other sources, and other sleep disorders in a mammal, comprising administering to a mammal in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

This invention also relates to a method of increasing slow wave sleep and increasing growth hormone secretion in a human subject comprising administering to a human subject in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

This invention also relates to a method of treating a disorder or condition selected from the group consisting of respiratory diseases, particularly those associated with excess mucus secretion, such as chronic obstructive airways disease, bronchopneumonia, chronic bronchitis, cystic fibrosis, adult respiratory distress syndrome, and bronchospasm; cough, whooping cough, angiotensin converting enzyme (ACE) induced cough, pulmonary tuberculosis, allergies such as eczema and rhinitis; contact dermatitis, atopic dermatitis, urticaria, and other eczematoid dermatitis; itching, hemodialysis associated itching; inflammatory diseases such as inflammatory bowel disease, psoriasis, osteoarthritis, cartilage damage (*e.g.*, cartilage damage resulting from physical activity or osteoarthritis), rheumatoid arthritis, psoriatic arthritis, asthma, pruritis and sunburn; and hypersensitivity disorders such as poison ivy in a mammal, comprising administering to a mammal in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

This invention also relates to a method of treating a disorder or condition selected from the group consisting of neurodegenerative disorders, such as Parkinson's disease (PD), Huntington's disease (HD) and Alzheimer's disease (AD); delirium, dementias (*e.g.*, senile dementia of the Alzheimer's type, senile dementia, vascular dementia, HIV-1 associated dementia, AIDS dementia complex (ADC), dementias due to head trauma, Parkinson's disease, Huntington's disease, Pick's disease, Creutzfeldt-Jakob disease, or due to multiple etiologies), amnesic disorders, other cognitive or memory disorders, and behavioral symptoms of dementia in a mammal, comprising administering to a mammal in need of such treatment a therapeutically

effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

This invention also relates to a method of treating a disorder or condition selected from the group consisting of Down's syndrome; Sjogren's syndrome, hypertension, hematopoiesis, postoperative neuroma, benign prostatic hypertrophy, periodontal disease, hemorrhoids and anal fissures, infertility, reflex sympathetic dystrophy, hepatitis, tenalgia attendant to hyperlipidemia, vasodilation, fibrosing and collagen diseases such as scleroderma and eosinophilic fascioliasis; and vasospastic diseases such as angina, migraine and Reynaud's disease in a mammal, comprising administering to a mammal in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

This invention also relates to a method of treating a disorder or condition selected from the group consisting of ophthalmic diseases such as dry eye syndrome, conjunctivitis, vernal conjunctivitis, and the like; and ophthalmic conditions associated with cell proliferation such as proliferative vitreoretinopathy in a mammal, comprising administering to a mammal in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

This invention also relates to a method of treating a disorder or condition selected from the group consisting of autism, attention deficit hyperactivity disorder (ADHD), angiogenesis (*i.e.*, use for the inhibition of angiogenesis), Reiter's syndrome and anthropathies in a mammal, comprising administering to a mammal in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

This invention also relates to a method of treating a disorder or condition selected from the group consisting of substance-related disorders arising from the use of alcohol, amphetamines (or amphetamine-like substances) caffeine, cannabis, cocaine, hallucinogens, inhalants and aerosol propellants, nicotine, opioids, phenylglycidine derivatives, sedatives, hypnotics, and anxiolytics, which substance-related disorders include dependence and abuse, intoxication, withdrawal, intoxication delirium and

withdrawal delirium; and addiction disorders involving addictions to behaviors (e.g., addictions to gambling and other addictive behaviors) in a mammal, comprising administering to a mammal in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

This invention also relates to a method of treating a disorder or condition selected from the group consisting of Down's syndrome; demyelinating diseases such as multiple sclerosis (MS) and amyotrophic lateral sclerosis (ALS) in a mammal, comprising administering to a mammal in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

This invention also relates to a method of treating a disorder or condition selected from the group consisting of pervasive development disorder, fibromyalgia, human immunodeficiency virus (HIV) infections; HIV encephalopathy; dissociative disorders such as body dysmorphic disorders; eating disorder such as anorexia and bulimia; ulcerative colitis; Crohn's disease; irritable bowel syndrome; chronic pancreatitis, chronic fatigue syndrome; sudden infant death syndrome (SIDS); overactive bladder; lower urinary tract symptoms of overactive bladder; chronic cystitis; chemotherapy induced cystitis; cough, angiotensin converting enzyme (ACE) induced cough, itch, hiccups, premenstrual syndrome, premenstrual dysphoric disorder, amenorrheic disorders such as dysmenorrhea; reflex sympathetic dystrophy such as shoulder/hand syndrome; plasma extravasation resulting from cytokine chemotherapy; disorders of bladder function such as chronic cystitis, bladder detrusor hyper-reflexia, inflammation of the urinary tract and urinary incontinence, including urinary urge incontinence, overactive bladder, stress incontinence and mixed incontinence; fibrosing and collagen diseases such as scleroderma and eosinophilic fasciitis; blood flow disorders caused by vasodilation and vasospastic diseases such as angina and Raynaud's disease; sexual dysfunctions including premature ejaculation and male erectile dysfunction in a mammal, comprising administering to a mammal in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.



This invention also relates to a method of treating a disorder or condition selected from the group consisting of movement disorders such as primary movement disorders, akinesias, dyskinesias (*e.g.*, familial paroxysmal dyskinesia, tardive dyskinesia, tremor, chorea, myoclonus, tics and other dyskinesias) spasticities, Tourette's syndrome, Scott syndrome, palsys (*e.g.*, Bell's palsy, cerebral palsy, birth palsy, brachial palsy, wasting palsy, ischemic palsy, progressive bulbar palsy and other palsys), akinetic-rigid syndrome; extra-pyramidal movement disorders such as medication-induced movement disorders, for example, neuroleptic-induced Parkinsonism, neuroleptic malignant syndrome, neuroleptic-induced acute dystonia, neuroleptic-induced acute akathisia, neuroleptic-induced tardive dyskinesia and medication-induced postural tremour; restless legs syndrome and movement disorders associated with Parkinson's disease or Huntington's disease in a mammal, comprising administering to a mammal in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

This invention also relates to a method of treating a disorder or condition selected from the group consisting of mastalgia syndromes, motion sickness, systemic lupus erythematosus and immune dysfunctions (*e.g.*, stress induced immune dysfunctions such as idiopathic immune dysfunctions, post infection immune dysfunctions, post lumpectomy immune dysfunctions, porcine stress syndrome, bovine shipping fever, equine paroxysmal fibrillation, confinement dysfunction in chicken, sheering stress in sheep, and human-animal interaction stress in dogs) in a mammal, comprising administering to a mammal in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

This invention also relates to a method of treating a disorder or condition selected from the group consisting of gastrointestinal (GI) disorders, including inflammatory gastrointestinal disorders such as inflammation bowel disease, disorders caused by *helicobacter pylori* and diseases of the GI tract such as gastritis, proctitis, gastroduodenal ulcers, peptic ulcers, dyspepsia, disorders associated with the neuronal control of viscera, ulcerative colitis, Crohn's disease, irritable bowel syndrome and emesis, including post operative nausea and post operative vomiting, and including acute, delayed or

anticipatory emesis (emesis includes emesis induced by chemotherapy, radiation, toxins, viral or bacterial infections, pregnancy, vestibular disorders, for example, motion sickness, vertigo, dizziness and Meniere's disease, surgery, migraine, variations in intracranial pressure, gastro-oesophageal reflux disease, acid indigestion, over indulgence in food or drink, acid stomach, waterbrash or regurgitation, heartburn, for example, episodic, nocturnal or meal-induced heartburn, and dyspepsia) in a mammal, comprising administering to a mammal in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

This invention also relates to a method of treating a disorder or condition selected from the group consisting of neoplasms, including breast tumours, gastric carcinomas, gastric lymphomas, neuroganglioblastomas and small cell carcinomas such as small cell lung cancer in a mammal, comprising administering to a mammal in need of such treatment a therapeutically effective amount of a compound of the formula I or a pharmaceutically acceptable salt thereof.

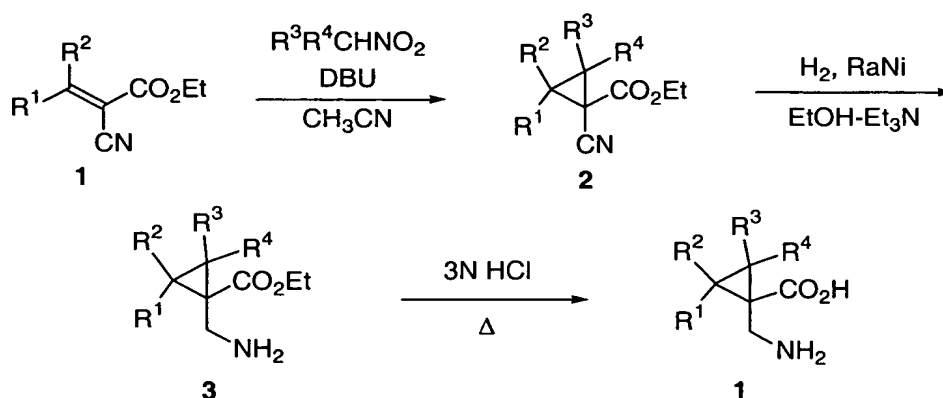
The foregoing methods are also referred to herein, collectively, as the "invention methods".

The term "treating", as used herein, refers to reversing, alleviating, inhibiting the progress of, or preventing the disorder or condition to which such term applies, or preventing one or more symptoms of such condition or disorder. The term "treatment", as used herein, refers to the act of treating, as "treating" is defined immediately above.

## DETAILED DESCRIPTION OF THE INVENTION

The compounds of the present invention can be prepared as described in the following reaction schemes and discussion. In the reaction schemes and discussion that follow, R<sup>1</sup> through R<sup>4</sup>, unless otherwise indicated, are defined as above.

**Scheme 1**

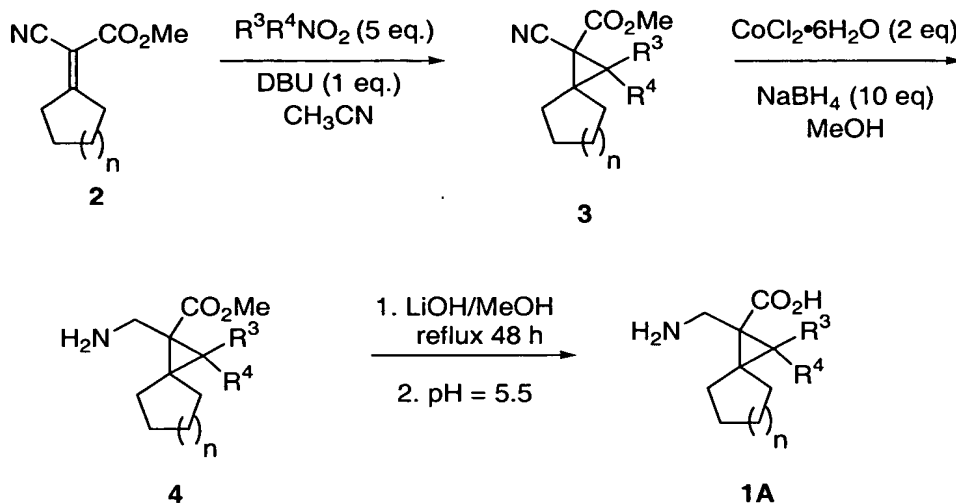


Referring to Scheme 1, a compound of the formula **1** is reacted with a compound of the formula R<sup>4</sup>R<sup>3</sup>NO<sub>2</sub>, in the presence of 1,8-diazabicyclo[5.4.0]undec-7-one (DBU), in an acetonitrile solvent, or in the presence of potassium carbonate in an ethanol solvent, to yield the corresponding compound of formula **2**. Preferably, one equivalent of DBU is used per five equivalents of R<sup>4</sup>R<sup>3</sup>NO<sub>2</sub>. This reaction is generally carried out at a temperature from about 60°C to about 80°C, preferably at about 60°C. Reaction of the resulting compound of formula **2** with triethylamine in an ethanol solvent, under a hydrogen gas pressure of about 1 atmosphere to about 5 atmospheres, preferably about 1 atmosphere, in the presence of Raney nickel, at a temperature of about 20°C to about 60°C, preferably at about room temperature, yields the corresponding compound of formula **3**.

The compound of formula **3** can be converted into the desired compound of formula **1** by reacting it with hydrochloric acid (HCl), preferably 3N HCl, at a temperature from about 80°C to about the reflux temperature of the reaction mixture, preferably at about the reflux temperature.

Scheme 2 illustrates a preferred method of synthesizing compounds of the formula I wherein  $R^1$  and  $R^2$ , together with the carbon to which they are attached, form a cyclopentyl, cyclohexyl or cycloheptyl ring.

**Scheme 2**

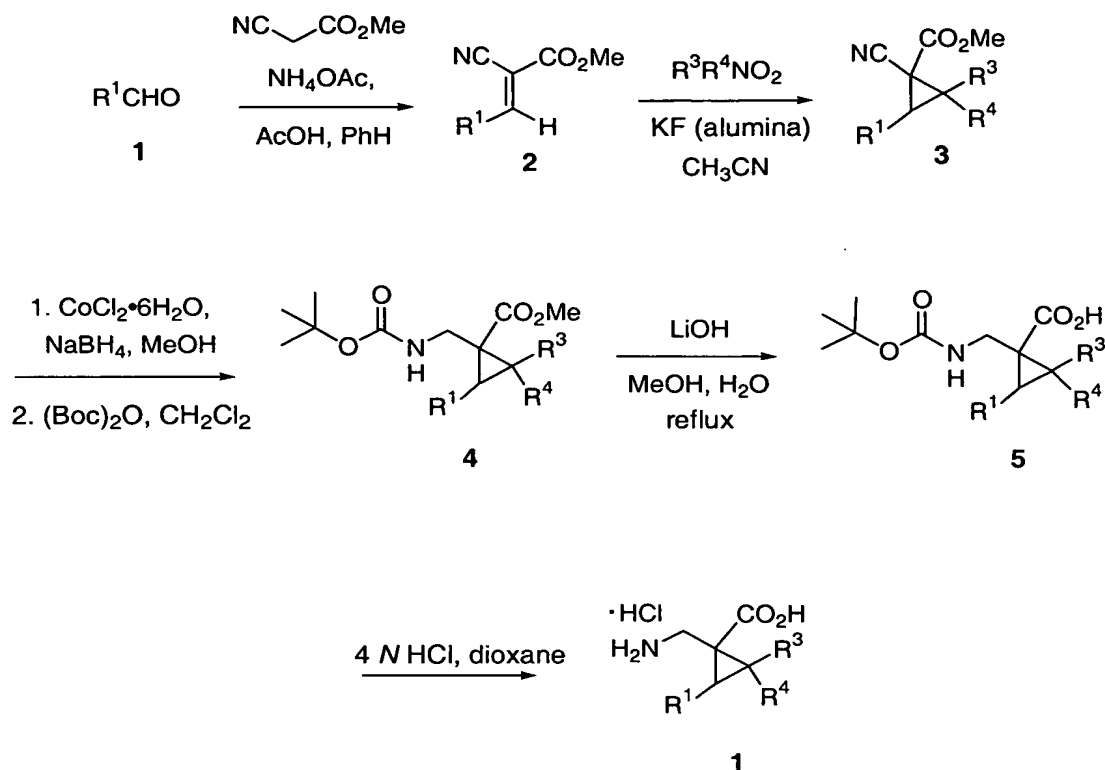


Referring to Scheme 2, in compounds of the formula 2, 3, 4 and 5,  $n$  is 1, 2 or 3, and the ring containing  $(\text{CH}_2)_n$  can be optionally substituted by one or two substituents selected from the group of substituents set forth in the definition of  $R^1$  and  $R^2$  above. Compounds of the formula 2 can be converted into the corresponding compounds of formula 3 using the procedure described above and depicted in Scheme 1 for forming compounds of the formula 2 (Scheme 1) from compounds of the formula 1 (Scheme 1). Reaction of the compounds of formula 3 with cobalt chloride hexahydrate and sodium borohydride in ethanol or a mixture of a lower alcohol and water, at a temperature from about  $0^\circ\text{C}$  to about  $40^\circ\text{C}$  yields the corresponding compounds of formula 4. Preferably, two equivalents of cobalt chloride hexahydrate and 10 equivalents of sodium borohydride are used, and the reaction is conducted in methanol at about room temperature.

The desired compound of formula 1A can then be formed by reacting the corresponding compounds of formula 4 with lithium hydroxide in methanol

or another lower alcohol, e.g., ethanol or n-butanol, at a temperature from about 50°C to about 70°C, preferably at the reflux temperature, to form the corresponding lithium carboxylates, and then reacting the resulting carboxylates with a strong mineral acid. Preferably, the carboxylates are converted into the corresponding acids *in situ* by cooling the reaction mixture to a temperature between about 0°C and about 25°C and adding enough hydrochloric acid to bring the pH of the mixture to about 5.5.

### Sch me 3



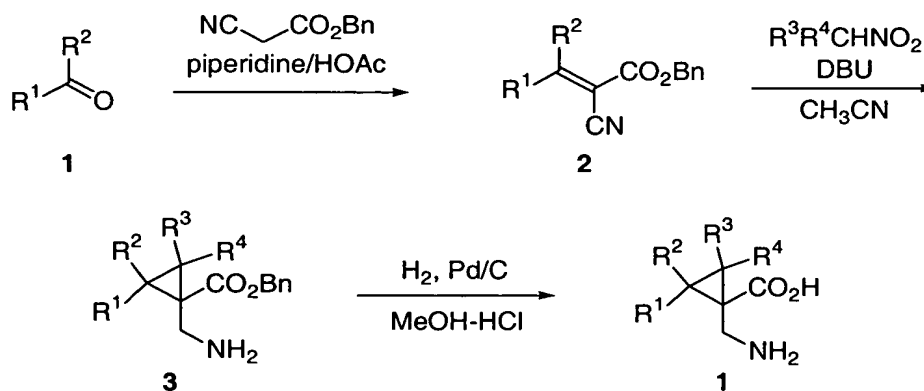
Referring to Scheme 3, the aldehyde of formula 1 is converted into the ester of formula 2 by reacting it with a compound of the formula  $\text{NCCH}_2\text{CO}_2\text{CH}_3$ , ammonium acetate and glacial acetic acid in benzene at a temperature from about  $40^\circ\text{C}$  to about the reflux temperature, preferably at about the reflux temperature. Reaction of the compounds of formula 2 with a compound of the formula  $\text{R}^3\text{R}^4\text{NO}_2$ , in an acetonitrile solvent, in the presence of a potassium fluoride or alumina catalyst, at a temperature from about  $40^\circ\text{C}$  to about the reflux temperature, preferably at about the reflux temperature, yields the corresponding compounds of formula 3.

The esters of formula 3 can then be converted into the corresponding amino protected esters of formula 4 by the following two step process. First, the compounds of formula 3 are reacted with cobalt chloride hexahydrate and ammonium borohydride in ethanol or a mixture of a lower alcohol and water, at a temperature from about  $0^\circ\text{C}$  to about  $40^\circ\text{C}$ , to convert the cyano group into a methylamino group. Preferably, two equivalents of cobalt chloride

hexahydrate and 10 equivalents of sodium borohydride are used, and the reaction is conducted in methanol at about room temperature. The amino group of the resulting compound is then protected by reacting such compound with di-*tert*-butyldicarbonate in dichloromethane. The latter reaction is also generally conducted at a temperature from about 0°C to about 40°C, and is preferably conducted at about room temperature.

The desired compounds of the formula I can then be formed from the corresponding compounds of formula 5 using methods well known to those of skill in the art. For example, reaction of the compounds of formula 5 with an appropriate acid such as hydrochloric acid in dioxane, ethyl ether or a lower alcohol solvent, or trifluoroacetic acid will yield the corresponding acid addition salts of the compounds of formula I. The compounds of formula I can be prepared from their acid addition salts as described above in the Summary of the Invention.

**Scheme 4**



Referring to Scheme 4, compounds of the formula 2 can be prepared from the corresponding ketones of formula 1 by reacting the ketones with a compound of the formula  $CNCH_2CO_2Bn$ , wherein Bn is benzyl, (benzylcyanoacetate) in an acetic acid solvent, in the presence of piperidine, pyrrolidine, or ammonium acetate, preferable piperidine, at a temperature from about 0°C to about room temperature, preferably at about room temperature. Reaction of the compounds of formula 2 with a compound of the

formula  $R^3R^4NO_2$  in the presence of 1,8-diazabicyclo[5.4.0]undec-7-one (DBU), in an acetonitrile solvent, or in the presence of potassium carbonate in an ethanol solvent, yields the corresponding compounds of formula 3. Preferably, one equivalent of DBU is used per five equivalents of  $R^4R^3NO_2$ . This reaction is generally carried out at a temperature from about 60°C to about 80°C, preferably at about 60°C.

The desired acids of the formula I can be formed from the corresponding benzyl esters of formula 4 using standard methods well known to those of skill in the art. For example, via hydrogenation, by reacting the compounds of formula 4 with hydrogen gas, using a hydrogen gas pressure of from 1 – 5 atmospheres, preferably about 1 atmosphere, and a palladium on carbon catalyst or other suitable hydrogenation catalyst, in a methanol or ethanol solvent, at a temperature from about 0°C to about room temperature, preferably at about room temperature.

All that is required to practice the method of this invention is to administer a compound of the formula I, or a pharmaceutically acceptable salt thereof, in an amount that is therapeutically effective to treat one or more of the disorders or conditions referred to above. Such therapeutically effective amount will generally be from about 1 to about 300 mg/kg of subject body weight per day. Typical doses will be from about 10 to about 5000 mg/day for an adult subject of normal weight. In a clinical setting, regulatory agencies such as, for example, the Food and Drug Administration ("FDA") in the U.S. may require a particular therapeutically effective amount.

In determining what constitutes an effective amount or a therapeutically effective amount of a compound of the formula I, or a pharmaceutically acceptable salt thereof, for treating one or more of the disorders or conditions referred to above according to the invention method, a number of factors will generally be considered by the medical practitioner or veterinarian in view of the experience of the medical practitioner or veterinarian, published clinical studies, the subject's age, sex, weight and general condition, as well as the type and extent of the disorder or condition being treated, and the use of other medications, if any, by the subject. As such, the administered dose may fall within the ranges or concentrations recited above, or may vary outside, *i.e.*,



either below or above, those ranges depending upon the requirements of the individual subject, the severity of the condition being treated, and the particular therapeutic formulation being employed. Determination of a proper dose for a particular situation is within the skill of the medical or veterinary arts. Generally, treatment may be initiated using smaller dosages of the  $\alpha_2\delta$  ligand that are less than optimum for a particular subject. Thereafter, the dosage can be increased by small increments until the optimum effect under the circumstance is reached. For convenience, the total daily dosage may be divided and administered in portions during the day, if desired.

Pharmaceutical compositions of a compound of the formula I, or a pharmaceutically acceptable salt thereof, are produced by formulating the active compound in dosage unit form with a pharmaceutical carrier. Some examples of dosage unit forms are tablets, capsules, pills, powders, aqueous and nonaqueous oral solutions and suspensions, and parenteral solutions packaged in containers containing either one or some larger number of dosage units and capable of being subdivided into individual doses.

Some examples of suitable pharmaceutical carriers, including pharmaceutical diluents, are gelatin capsules; sugars such as lactose and sucrose; starches such as corn starch and potato starch; cellulose derivatives such as sodium carboxymethyl cellulose, ethyl cellulose, methyl cellulose, and cellulose acetate phthalate; gelatin; talc; stearic acid; magnesium stearate; vegetable oils such as peanut oil, cottonseed oil, sesame oil, olive oil, corn oil, and oil of theobroma; propylene glycol, glycerin; sorbitol; polyethylene glycol; water; agar; alginic acid; isotonic saline, and phosphate buffer solutions; as well as other compatible substances normally used in pharmaceutical formulations.

The compositions to be employed in the invention can also contain other components such as coloring agents, flavoring agents, and/or preservatives. These materials, if present, are usually used in relatively small amounts. The compositions can, if desired, also contain other therapeutic agents commonly employed to treat the disorder or condition being treated.

The percentage of the active ingredients in the foregoing compositions can be varied within wide limits, but for practical purposes it is preferably

present in a concentration of at least 10% in a solid composition and at least 2% in a primary liquid composition. The most satisfactory compositions are those in which a much higher proportion of the active ingredient is present, for example, up to about 95%.

In tablets, the active component is mixed with the carrier having the necessary binding properties in suitable proportions and compacted in the shape and size desired.

The powders and tablets preferably contain from five or ten to about seventy percent of the active compound. Suitable carriers are magnesium carbonate, magnesium stearate, talc, sugar, lactose, pectin, dextrin, starch, gelatin, tragacanth, methylcellulose, sodium carboxymethylcellulose, a low melting wax, cocoa butter, and the like. The term "preparation" is intended to include the formulation of the active compound with encapsulating material as a carrier providing a capsule in which the active component with or without other carriers, is surrounded by a carrier, which is thus in association with it. Similarly, cachets and lozenges are included. Tablets, powders, capsules, pills, cachets, and lozenges can be used as solid dosage forms suitable for oral administration.

For preparing suppositories, a low melting wax, such as a mixture of fatty acid glycerides or cocoa butter, is first melted and the active component is dispersed homogeneously therein, as by stirring. The molten homogeneous mixture is then poured into convenient sized molds, allowed to cool, and thereby to solidify.

Liquid form preparations include solutions, suspensions, and emulsions, for example, water or water propylene glycol solutions. For parenteral injection liquid preparations can be formulated in solution in aqueous polyethylene glycol solution.

Aqueous solutions suitable for oral use can be prepared by dissolving the active component in water and adding suitable colorants, flavors, stabilizing and thickening agents as desired.

Aqueous suspensions suitable for oral use can be made by dispersing the finely divided active component in water with viscous material, such as natural or synthetic gums, resins, methylcellulose, sodium carboxymethylcellulose, and other well-known suspending agents.

Also included are solid form preparations that are intended to be converted, shortly before use, to liquid form preparations for oral administration. Such liquid forms include solutions, suspensions, and emulsions. These preparations may contain, in addition to the active component, colorants, flavors, stabilizers, buffers, artificial and natural sweeteners, dispersants, thickeners, solubilizing agents, and the like.

The pharmaceutical preparation is preferably in unit dosage form. In such form the preparation is subdivided into unit doses containing appropriate quantities of the active component. The unit dosage form can be a packaged preparation, the package containing discrete quantities of preparation, such as packeted tablets, capsules, and powders in vials or ampoules. Also, the unit dosage form can be a capsules, tablet, cachet, or lozenge itself, or it can be the appropriate number of any of these in packaged form.

The degree of binding to the  $\alpha 2\delta$  subunit can be determined using the radioligand binding assay using [3H]gabapentin and the  $\alpha 2\delta$  subunit derived from porcine brain tissue, as described by N. S. Gee *et al.*, *J. Biol. Chem.*, 1996, 271:5879-5776.

The compounds of the invention show good binding affinity to the  $\alpha 2\delta$  subunit. Gabapentin (Neurontin®) is about 0.10 to 0.12  $\mu$ M in this assay. Since the compounds of the instant invention also bind to the subunit, they are expected to exhibit pharmacologic properties comparable to gabapentin. For example, as agents for convulsions, anxiety, and pain.

The radioligand binding assay using [3H]-gabapentin and the  $\alpha 2\delta$ -subunit derived from porcine brain tissue can be used to determine the binding affinity of the compounds of the present invention for the  $\alpha 2\delta$ -subunit. (See, Gee, Nicolas S *et al.* "The novel anticonvulsant drug, gabapentin (Neurontin), binds to the  $\alpha 2\delta$  subunit of a calcium channel". *J. Biol. Chem.* (1996), 271(10), 5768-76). In the above assay, the title compound of

Example 1 exhibited an  $IC_{50}$  of 0.037  $\mu M$ , the title compound of Example 3 exhibited an  $IC_{50}$  of 0.34  $\mu M$ , and the title compound of Example 6 exhibited an  $IC_{50}$  of 0.89  $\mu M$ .

The *In vivo* activity of compounds of this invention can be determined in animal models of hyperalgesia (See Sluka, K., *et al.* 2001, "Unilateral Intramuscular Injections Of Acidic Saline Produce A Bilateral, Long-Lasting Hyperalgesia", *Muscle Nerve* 24: 37-46; Dixon, W., 1980, "Efficient analysis of experimental observations". *Ann Rev Pharmacol Toxicol* 20:441-462; Randall L.O. and Selitto J.J., "A Method For Measurement Of Analgesic Activity On Inflamed Tissue," *Arch. Int. Pharmacodyn.*, 1957;4:409-419; Hargreaves K., Dubner R., Brown F., Flores C., and Joris J. "A New And Sensitive Method For Measuring Thermal Nociception In Cutaneous Hyperalgesia". *Pain.* 32:77-88, 1988.), anxiety (Vogel JR, Beer B, and Clody DE, "A Simple And Reliable Conflict Procedure For Testing Anti-Anxiety Agents", *Psychopharmacologia* 21:1-7, 1971).

The following Examples illustrate the preparation of the compounds of the present invention. Melting points are uncorrected. NMR data are reported in parts per million and are referenced to the deuterium lock signal from the sample solvent.

## EXAMPLES

### **Example 1**

#### 1-AMINOMETHYL-SPIRO[2.5]OCTANE-1-CARBOXYLIC ACID HYDROCHLORIDE

##### **A. 1-Cyano-spiro[2.5]octane-1-carboxylic acid ethyl ester**

To a solution of cyano-cyclohexylidene-acetic acid ethyl ester (1.37g, 7.09 mmol) in 30 mL acetonitrile was added nitromethane (1.92 mL, 35.5 mmol), followed by 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) (1.06 mL, 7.09 mmol) resulting in an orange solution. The reaction was stirred for 2.5 hours, then partitioned between ethyl ether (Et<sub>2</sub>O) and 1N hydrochloric acid (HCl) (aq). The phases were separated, and the organic phase washed with brine, dried over magnesium sulfate (MgSO<sub>4</sub>), and concentrated. Flash chromatography of the residue (5% ethyl acetate (EtOAc)/hexanes) afforded 1.1g (75%) of 1-cyano-spiro[2.5]octane-1-carboxylic acid ethyl ester as a colorless oil. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 4.22 (m, 2H), 1.77 (d, *J* = 5.1 Hz, 1H), 1.42-1.72 (m, 10H), 1.40 (d, *J* = 5.1 Hz, 1H), 1.30 (t, *J* = 7.1 Hz, 3H). <sup>13</sup>C NMR δ 166.40, 118.60, 62.72, 40.20, 34.67, 29.01, 28.75, 25.69, 25.54, 25.28, 24.66, 14.38. LRMS: *m/z* 208.0 (*M*+1). IR: 2239, 1732 cm<sup>-1</sup>. Anal. Calcd for C<sub>12</sub>H<sub>17</sub>NO<sub>2</sub>: C, 69.54; H, 8.27; N, 6.76. Found: C, 69.41; H, 8.33; N, 6.75.

##### **B. 1-Aminomethyl-spiro[2.5]octane-1-carboxylic acid ethyl ester**

To a solution of 1-cyano-spiro[2.5]octane-1-carboxylic acid ethyl ester (7.1g, 34.2 mmol) in 95 mL ethanol (EtOH) was added triethylamine (5.0mL) and Raney nickel (4.0g). The mixture was hydrogenated in a Parr shaker at 48 psi for 70 hours, filtered, and concentrated. Flash chromatography of the residue (5→10→15% MeOH/methylene chloride (CH<sub>2</sub>Cl<sub>2</sub>)) provided 5.0g (69%) of 1-aminomethyl-spiro[2.5]octane-1-carboxylic acid ethyl ester as a colorless oil. <sup>1</sup>H NMR δ 4.15 (q, *J* = 7.1Hz, 2H), 3.23 (d, *J* = 13.9 Hz, 1H), 2.65 (d, *J* = 13.9 Hz, 1H), 1.41-1.57 (m, 10H), 1.24 (m, 4H), 0.53 (d, *J* = 4.9 Hz, 1H).

##### **C. 1-Aminomethyl-spiro[2.5]octane-1-carboxylic acid hydrochloride**

To 1-aminomethyl-spiro[2.5]octane-1-carboxylic acid ethyl ester (5.0g, 23.7 mmol) was added 50 mL 3N HCl (aq), and the mixture was refluxed for 72 hours. The crude  $^1\text{H}$  NMR indicated the hydrolysis had proceeded to 50% completion. The solution was concentrated, and the residue washed exhaustively with  $\text{Et}_2\text{O}$  to remove the starting material, until a fine white solid was obtained. The combined solids were washed again with  $\text{Et}_2\text{O}$  (3 X 15mL) to give a chalky solid. A small portion of the batch was recrystallized from MeOH/EtOAc to furnish 0.17g (3.3%) of 1-aminomethyl-spiro[2.5]octane-1-carboxylic acid as a colorless solid, mp  $>250^\circ\text{C}$  (dec):  $^1\text{H}$  NMR ( $\text{D}_2\text{O}$ )  $\delta$  3.37 (d,  $J = 13.4$  Hz, 1H), 2.83 (d,  $J = 13.4$  Hz, 1H), 1.21-1.33 (m, 10H), 0.99 (d,  $J = 5.1$  Hz, 1H), 0.47 (d,  $J = 5.1$  Hz, 1H). Anal. Calcd for  $\text{C}_{10}\text{H}_{17}\text{NO}_2 \cdot \text{HCl}$ : C, 54.67; H, 8.26; N, 6.37. Found: C, 54.77; H, 8.41; N, 6.31. A second crop was also obtained (0.34g, 6.6%). Anal. Calcd for  $\text{C}_{10}\text{H}_{17}\text{NO}_2 \cdot \text{HCl}$ : C, 54.67; H, 8.26; N, 6.37. Found: C, 54.71; H, 8.42; N, 6.22. The  $\text{Et}_2\text{O}$  washings were concentrated to provide 1-aminomethyl-spiro[2.5]octane-1-carboxylic acid ethyl ester hydrochloride as a colorless solid, mp  $118\text{-}120^\circ\text{C}$ :  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  8.39 (br s, 3H), 4.23 (m, 2H), 3.66 (m, 1H), 3.31 (m, 1H), 1.85 (m, 1H), 1.65 (m, 1H), 1.42-1.54 (m, 9H), 1.28 (t,  $J = 7.1$  Hz, 3H), 1.03 (d,  $J = 5.4$  Hz, 1H). Anal. Calcd for  $\text{C}_{12}\text{H}_{21}\text{NO}_2 \cdot \text{HCl}$ : C, 58.17; H, 8.95; N, 5.65. Found: C, 58.31; H, 8.87; N, 5.51.

The following compounds were prepared according to the procedure described in Example 1.

### Example 2

#### 1-AMINOMETHYL-SPIRO[2.4]HEPTANE-1-CARBOXYLIC ACID HYDROCHLORIDE

$^1\text{H}$  NMR ( $\text{D}_2\text{O}$ )  $\delta$  3.31 (d,  $J = 13.7$  Hz, 1H), 2.87 (d,  $J = 13.9$  Hz, 1H), 1.65 (m, 1H), 1.49 (m, 5H), 1.37 (d,  $J = 4.6$  Hz, 1H), 1.31 (m, 1H), 1.03 (m, 1H), 0.92 (d,  $J = 4.6$  Hz, 1H). LRMS:  $m/z$  167.9 (M-1).

### Exempl 3

#### 1-AMINOMETHYL-SPIRO[2.6]NONANE-1-CARBOXYLIC ACID HYDROCHLORIDE

mp >195 °C (dec).  $^1\text{H}$  NMR ( $\text{D}_2\text{O}$ )  $\delta$  3.60 (d,  $J$  = 13.4 Hz, 1H), 2.83 (d,  $J$  = 13.7 Hz, 1H), 1.34-1.64 (m, 12H), 1.27 (d,  $J$  = 4.9 Hz, 1H), 0.76 (d,  $J$  = 5.1 Hz, 1H).

#### Example 4

##### 1-AMINOMETHYL-2-METHYL-SPIRO[2.6]NONANE-1-CARBOXYLIC ACID

(prepared *via* cyclopropanation with nitroethane):  $^1\text{H}$  NMR ( $\text{D}_2\text{O}$ )  $\delta$  3.27 (d,  $J$  = 13.7 Hz, 1H), 2.87 (d,  $J$  = 13.7 Hz, 1H), 1.27-1.46 (m, 12H), 0.90 (d,  $J$  = 6.6 Hz, 3H), 0.66 (m, 1H). LRMS:  $m/z$  210.1 (M-1). Anal. Calcd for  $\text{C}_{12}\text{H}_{21}\text{NO}_2$ : C, 68.21; H, 10.02; N, 6.63. Found: C, 67.65; H, 10.31; N, 6.57.

#### Example 5

##### 1-AMINOMETHYL-SPIRO[2.4]HEPTANE-1-CARBOXYLIC ACID

###### A. Cyano-Cyclopentylidene-Acetic Acid Methyl Ester

To a solution of cyclopentanone (84.1 g, 1 mol) in dry benzene (100 mL) was added methyl cyanoacetate (99.1 g, 1 mol), ammonium acetate (10 g) and glacial acetic acid (20 mL). The reaction mixture was heated to reflux using Dean-Stark apparatus for 12 hours and allowed to cool to room temperature. Excess of solvents was removed in vacuo and the residue was dissolved in EtOAc (400 mL). The organic layer was washed with water, dried ( $\text{Na}_2\text{SO}_4$ ) and evaporated to give the product as pale yellow oil. Further purification of the pale yellow oil by distillation (10 mm Hg, 140-145°C) provided cyano-cyclopentylidene-acetic acid methyl ester (130 g, 79%) as a colorless oil:  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ )  $\delta$  1.80 (m, 4H), 2.80 (t, 2H), 3.0 (t, 2H), 3.80 (s, 3H);  $^{13}\text{C}$  NMR (75 MHz,  $\text{CDCl}_3$ )  $\delta$  25.4, 26.9, 35.8, 38.1, 52.5, 100.7, 115.8, 162.6, 188.3.

###### B. 1-Cyano-spiro[2.4]heptane-1-carboxylic acid methyl ester

To a solution of cyano-cyclopentylidene-acetic acid methyl ester (20.8 g, 126 mmol) in acetonitrile (500 mL) was added nitromethane (34 mL, 630 mmol, 5 eq) followed by dropwise addition of 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) (18.8 mL, 126 mmol). The reaction solution turned orange upon

the addition of DBU. The reaction mixture was stirred at room temperature for 16 hours. Another portion of DBU (1 mL) was added and stirred for 1 hour. The reaction mixture was partitioned between ether (1 L) and 1N HCl (400 mL) and the layers separated. The organic layer was washed with 1N HCl (2 x 300 mL), brine (2 x 200 mL), dried over sodium sulfate, filtered and evaporated. The residue was chromatographed on a wet-packed silica gel column eluting with 4-6% ethyl acetate/hexanes. The appropriate fractions were combined and evaporated to furnish 14.0 g (62%) of 1-cyano-spiro[2.4]heptane-1-carboxylic acid methyl ester as a clear oil:  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ )  $\delta$  1.64 (d,  $J$  = 5.0 Hz, 1H), 1.70-1.88 (m, 7H), 2.14 (d,  $J$  = 5.0 Hz, 1H), 2.1-2.19 (m, 1H), 3.82 (s, 3H); MS (APCI)  $m/z$  180  $[\text{M}+\text{H}]^+$ .

C. 1-Aminomethyl-spiro[2.4]heptane-1-carboxylic acid methyl ester

To a solution of 1-cyano-spiro[2.4]heptane-1-carboxylic acid methyl ester (3.45 g, 19.3 mmol) in methanol (240 mL) was added cobalt chloride hexahydrate ( $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ ) (9.16 g, 38.5 mmol) to give a deep purple colored solution. Sodium borohydride (7.30 g, 193 mmol) was added portionwise over 10 minutes with caution to control the evolution of hydrogen and the exothermic reaction that ensued to give a black solution. The reaction mixture was stirred for 30 minutes under nitrogen after the addition was completed. The reaction was quenched carefully by the addition of 0.5N HCl (1.3 L). The solution was made alkaline (pH ~ 9) by the addition of concentrated ammonium hydroxide. The mixture was extracted with ethyl acetate (4 x 400 mL). The combined organic layers were dried over sodium sulfate, filtered and evaporated to afford 3.07 g (87%) of 1-aminomethyl-spiro[2.4]heptane-1-carboxylic acid methyl ester as a yellow oil:  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ )  $\delta$  0.74 (br d, 1H), 1.4-1.7 (m, 10H), 1.9 (m, 1H), 2.58 (d,  $J$  = 13.8 Hz, 1H), 3.16 (d,  $J$  = 13.8 Hz, 1H), 3.48 (s, 3H); MS (APCI)  $m/z$  184  $[\text{M}+\text{H}]^+$ .

D. 1-Aminomethyl-spiro[2.4]heptane-1-carboxylic acid

To a solution of 1-aminomethyl-spiro[2.4]heptane-1-carboxylic acid methyl ester (3.40 g, 18.6 mmol) was added methanol (75 mL) and lithium hydroxide-water ( $\text{LiOH} \cdot \text{H}_2\text{O}$ ) (1.55 g, 37.1 mmol). The mixture was heated to



reflux under nitrogen for 48 hours. The solvent was removed by evaporation under reduced pressure and the residue was dissolved in water (50 mL). With ice bath cooling, concentrated HCl (~2.5 mL) was added until the pH was adjusted to 6. A white precipitate was isolated by filtration and dried under vacuum to yield 1.22 g (39%) of 1-aminomethyl-spiro[2.4]heptane-1-carboxylic acid as an off-white solid: mp 231-235 °C (decomposition); <sup>1</sup>H NMR (300 MHz, D<sub>2</sub>O) δ 0.78 (d, *J* = 4.7 Hz, 1H), 1.32 (d, *J* = 4.7 Hz, 1H), 1.40 (m, 1H), 1.54-1.77 (m, 7 H), 2.86 (d, *J* = 13.2 Hz, 1H), 3.43 (d, *J* = 13.2 Hz, 1H); MS (APCI) *m/z* 170 [M+H]<sup>+</sup>. Anal. Calcd. For C<sub>9</sub>H<sub>15</sub>NO<sub>2</sub> · 1.1H<sub>2</sub>O: C, 57.18; H, 9.17; N, 7.41. Found: C, 57.38; H, 8.82; N, 7.09.

### Example 6

#### 1-AMINOMETHYL-2-ISOBUTYL-CYCLOPROPANECARBOXYLIC ACID HYDROCHLORIDE

A. 1-Cyano-2-isobutyl-cyclopropanecarboxylic acid ethyl ester. To a solution of 2-cyano-5-methyl-hex-2-enoic acid ethyl ester (0.74g, 4.08 mmol) in 16 mL acetonitrile was added nitromethane (1.11 mL, 20.4 mmol), followed by DBU (0.61 mL, 4.08 mmol) resulting in an orange solution. The reaction was heated to 60 °C for 16 hours, then cooled and partitioned between Et<sub>2</sub>O and 1N HCl (aq). The phases were separated, and the organic phase washed with brine, dried (MgSO<sub>4</sub>), and concentrated. Flash chromatography of the residue (5→10% EtOAc/hexanes) afforded 0.56g (70%) of 1-cyano-2-isobutyl-cyclopropanecarboxylic acid ethyl ester as a pale yellow oil. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 4.22 (m, 2H), 1.75-1.90 (m, 3H), 1.63 (m, 1H), 1.36 (m, 2H), 1.30 (t, *J* = 7.3 Hz, 3H), 0.95 (m, 6H). <sup>13</sup>C NMR δ 168.25, 117.72, 62.94, 39.12, 30.25, 28.12, 25.66, 22.63, 22.40, 19.56, 14.30. LRMS: *m/z* 196.0 (M+1). Anal. Calcd for C<sub>11</sub>H<sub>17</sub>NO<sub>2</sub>: C, 67.66; H, 8.78; N, 7.17. Found: C, 67.32; H, 8.74; N, 7.32.

B. 1-Aminomethyl-2-isobutyl-cyclopropanecarboxylic acid ethyl ester

To a solution of 1-cyano-2-isobutyl-cyclopropanecarboxylic acid ethyl ester (0.41g, 2.10 mmol) in 45 mL EtOH was added triethylamine (5.0mL) and Raney nickel (1.0g). The mixture was hydrogenated in a Parr shaker at 48 psi

for 18 hours, filtered, and concentrated. Flash chromatography of the residue (5→10% MeOH/CH<sub>2</sub>Cl<sub>2</sub>) provided 0.11g (26%) of 1-aminomethyl-2-isobutyl-cyclopropanecarboxylic acid ethyl ester as a colorless oil. <sup>1</sup>H NMR δ 4.10 (q, *J* = 7.1Hz, 2H), 2.90 (d, *J* = 14.2 Hz, 1H), 2.76 (d, *J* = 14.2 Hz, 1H), 1.63 (m, 1H), 1.52 (m, 2H), 1.34 (m, 1H), 1.22 (t, *J* = 7.1 Hz, 3H), 1.04 (m, 1H), 0.90 (m, 6H), 0.49 (m, 1H). <sup>13</sup>C NMR δ 175.51, 60.75, 42.42, 37.92, 30.61, 29.04, 26.46, 22.91, 22.63, 21.31, 14.49.

C. 1-Aminomethyl-2-isobutyl-cyclopropanecarboxylic acid hydrochloride

To 1-aminomethyl-2-isobutyl-cyclopropanecarboxylic acid ethyl ester (0.1g, 0.50 mmol) was added 10 mL 3N HCl (aq), and the mixture was refluxed for 60 hours. The crude <sup>1</sup>H NMR indicated the hydrolysis had proceeded to 100% completion. The solution was filtered while hot through a glass wool plug and concentrated. The solid residue was washed with Et<sub>2</sub>O (2 X 3mL) to give 86mg (100%) of 1-aminomethyl-2-isobutyl-cyclopropanecarboxylic acid hydrochloride as a colorless solid, mp >220 °C (dec): <sup>1</sup>H NMR (D<sub>2</sub>O) δ 3.34 (d, *J* = 13.7 Hz, 1H), 2.83 (d, *J* = 13.9 Hz, 1H), 1.57 (m, 1H), 1.47 (m, 1H), 1.37 (m, 1H), 1.30 (m, 1H), 1.00 (m, 1H), 0.72 (m, 7H). LRMS: *m/z* 169.9 (M-1). Anal. Calcd for C<sub>9</sub>H<sub>17</sub>NO<sub>2</sub>•HCl: C, 52.05; H, 8.74; N, 6.74. Found: C, 50.32; H, 8.15; N, 6.53.

### Example 7

#### 1-AMINOMETHYL-2-ISOPROPYL-CYCLOPROPANECARBOXYLIC ACID HYDROCHLORIDE

A. 2-Cyano-4-methyl-pent-2-enoic acid methyl ester

To a solution of isobutyraldehyde **1** (18.2 mL, 200 mmol) in dry benzene (20 mL) was added methyl cyanoacetate (18 mL, 200 mmol), ammonium acetate (2 g) and glacial acetic acid (4 mL). The reaction mixture was stirred at 60°C for 30 minutes and allowed to cool to room temperature. Excess of solvents was removed in vacuo and the residue was dissolved in EtOAc (200 mL). The organic layer was washed with water, dried over sodium sulfate and evaporated to give 2-cyano-4-methyl-pent-2-enoic acid methyl ester as pale yellow oil. Further purification of the pale yellow oil by

distillation (7 mm Hg) gave product **2** (27.4 g, 56%) as colorless oil:  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ )  $\delta$  1.16 (d,  $J$  = 6.6 Hz, 6H), 2.96-3.04 (m, 1H), 3.87 (s, 3H), 7.47 (d,  $J$  = 10.5 Hz, 1H).

B. 1-Cyano-2-isopropyl-cyclopropanecarboxylic acid methyl ester

To a solution of 2-cyano-4-methyl-pent-2-enoic acid methyl ester (10.5 g, 68.3 mmol) in dry acetonitrile (60 mL) was added nitromethane (5.5 mL, 103 mmol) and a portionwise addition of alumina-supported potassium fluoride (40% wt, 22 g). The reaction mixture was stirred under reflux for 2 hours and cooled to room temperature. The solid was removed by filtration through a short pad of celite and washed with acetonitrile. Excess of solvent was removed in vacuo and the residue was re-dissolved in ether. The ether layer was washed with water, brine, dried over sodium sulfate ( $\text{Na}_2\text{SO}_4$ ) and concentrated in vacuo. The crude product was purified by flash column chromatography using hexanes/EtOAc (8:2) as an eluent to afford 1-cyano-2-isopropyl-cyclopropanecarboxylic acid methyl ester (7.7 g, 68%) as colorless oil:  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ )  $\delta$  1.13 (t,  $J$  = 7.2 Hz, 6H), 1.39-1.45 (m, 2H), 1.65-1.74 (m, 1H), 1.81 (dd,  $J$  = 4.4, 8.9 Hz, 1H), 3.81 (s, 3H);  $^{13}\text{C}$  NMR (75 MHz,  $\text{CDCl}_3$ )  $\delta$  19.6, 21.8, 21.9, 25.3, 31.2, 39.3, 53.7, 117.6, 168.7.

C. 1-(*tert*-Butoxycarbonylamino-methyl)-2-isopropyl-cyclopropanecarboxylic acid methyl ester

To a solution of 1-cyano-2-isopropyl-cyclopropanecarboxylic acid methyl ester (7.7 g, 46.1 mmol) and cobaltous chloride hexahydrate (21.9 g, 92.2 mmol) in MeOH (560 mL) was added sodium borohydride ( $\text{NaBH}_4$ ) (17.4 g, 461 mmol) in portions. The black precipitate formed was stirred for 1 hour at room temperature and was quenched with 0.5N HCl (200 mL). After the black precipitate dissolved, excess of solvent was removed and aqueous layer was made alkaline by addition of 2N sodium hydroxide ( $\text{NaOH}$ ). The alkaline solution was added slowly to a solution of di-*tert*-butyldicarbonate (20.1 g, 92.2 mmol) in dichloromethane (400 mL). The reaction mixture was stirred at room temperature overnight and the organic layer was separated and washed with brine and dried ( $\text{Na}_2\text{SO}_4$ ). Evaporation of excess of solvent

followed by purification of the residue by column chromatography using hexanes/EtOAc (9:1) as an eluent furnished 1-(*tert*-butoxycarbonylamino-methyl)-2-isopropyl-cyclopropanecarboxylic acid methyl ester (10.9 g, 88%) as colorless oil:  $^1\text{H}$  NMR (300 MHz,  $\text{CD}_3\text{OD}$ )  $\delta$  0.76 (m, 1H), 0.97 (d,  $J$  = 6.3 Hz, 3H), 1.05 (d,  $J$  = 6.3 Hz, 3H), 1.26-1.31 (m, 3H), 1.43 (s, 9H), 3.23 (d,  $J$  = 14.3 Hz, 1H), 3.57 (d,  $J$  = 14.3 Hz, 1H), 3.69 (s, 3H);  $^{13}\text{C}$  NMR (75 MHz,  $\text{CD}_3\text{OD}$ )  $\delta$  20.5, 23.4, 23.6, 29.2, 38.1, 41.1, 53.0, 80.5, 158.5, 177.1; MS (APCI)  $m/z$  172 [ $\text{M}+\text{H}-100(\text{Boc})$ ] $^+$ .

D. 1-(*tert*-Butoxycarbonylamino-methyl)-2-isopropyl-cyclopropanecarboxylic acid

To a solution of 1-(*tert*-butoxycarbonylamino-methyl)-2-isopropyl-cyclopropanecarboxylic acid methyl ester (10.9 g, 40.2 mmol) in MeOH (320 mL) was added a solution of lithium hydroxide (LiOH) (4.2 g, 100 mmol) in water (98 mL). The reaction mixture was heated to reflux for 3 hours and cooled to room temperature. Excess of solvent was removed and the residue was dissolved in water (100 mL). The aqueous solution was washed with ether, acidified to pH = 3 with 2N HCl and extracted with EtOAc (2 x 150 mL). The combined organic phase was washed with brine, dried ( $\text{Na}_2\text{SO}_4$ ) and evaporation of the solvent provided 1-(*tert*-butoxycarbonylamino-methyl)-2-isopropyl-cyclopropanecarboxylic acid (9.0 g, 87%) as a colorless oil:  $^1\text{H}$  NMR (300 MHz,  $\text{CD}_3\text{OD}$ )  $\delta$  0.72 (m, 1H), 0.99 (d,  $J$  = 6.2 Hz, 3H), 1.06 (d,  $J$  = 6.2 Hz, 3H), 1.28-1.36 (m, 3H), 1.42 (s, 9H), 3.23 (d,  $J$  = 14.3 Hz, 1H), 3.54 (d,  $J$  = 14.3 Hz, 1H);  $^{13}\text{C}$  NMR (75 MHz,  $\text{CD}_3\text{OD}$ )  $\delta$  20.0, 23.0, 23.3, 28.8, 30.2, 37.6, 40.8, 80.2, 158.1, 178.5; MS (APCI)  $m/z$  258 [ $\text{M}+\text{H}$ ] $^+$ .

E. 1-Aminomethyl-2-isopropyl-cyclopropanecarboxylic acid hydrochloride

To a solution of 1-(*tert*-butoxycarbonylamino-methyl)-2-isopropyl-cyclopropanecarboxylic acid (2.05 g, 8.0 mmol) in dry 1,4-dioxane (40 mL) was added 4N HCl (40 mL, in 1,4-dioxane). The reaction mixture was stirred at room temperature overnight and ether was added (100 mL). The white solid was collected and dried to give 1-aminomethyl -2-isopropyl-cyclopropanecarboxylic acid hydrochloride (1.35 g, 88%): mp: 245-246  $^\circ\text{C}$ ;

$^1\text{H}$  NMR (300 MHz,  $\text{D}_2\text{O}$ )  $\delta$  0.94 (d,  $J$  = 6.5 Hz, 3H), 0.96 (m, 1H), 1.05 (d,  $J$  = 6.4 Hz, 3H), 1.23-1.31 (m, 1H), 1.49-1.59 (m, 2H), 2.85 (d,  $J$  = 13.7 Hz, 1H), 3.83 (d,  $J$  = 13.7 Hz, 1H);  $^{13}\text{C}$  NMR (75 MHz,  $\text{D}_2\text{O}$ )  $\delta$  22.3, 23.9, 27.8, 30.8, 39.6, 41.7, 179.6; MS (APCI)  $m/z$  158  $[\text{M}+\text{H}]^+$ . Anal. Calcd. For  $\text{C}_8\text{H}_{15}\text{NO}_2\text{-HCl}$ : C, 49.61; H, 8.33; N, 7.23; Cl, 18.31. Found: C, 49.76; H, 8.44; N, 7.11; Cl, 18.48.

### Example 8

#### 1-AMINOMETHYL-2,2-DIPROPYL-CYCLOPROPANECARBOXYLIC ACID

##### A. 2-Cyano-3-propyl-hex-2-enoic acid benzyl ester

To a mixture of 4-heptanone (2.0 mL, 14.3 mmol) and benzyl cyanoacetate (2.51 g, 14.3 mmol) at  $0^\circ\text{C}$  was added acetic acid (0.08 mL, 1.43 mmol), then piperidine (0.14 mL, 1.43 mmol) dropwise. The ice bath was removed, and stirring continued for 10 min. Additional acetic acid (0.08 mL) and piperidine (0.14 mL) were added, followed by the additional of oven-dried 4A molecular sieves such that stirring was not impeded. The mixture was stirred for 1h, then partitioned between EtOAc and sat. sodium bicarbonate ( $\text{NaHCO}_3$ ) (aq). The phases were separated, and the organic phase washed with brine, dried ( $\text{MgSO}_4$ ), and concentrated to provide 1.03 g (27%) of 2-cyano-3-propyl-hex-2-enoic acid benzyl ester as a colorless oil.  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  7.35 (m, 5H), 5.24 (s, 2H), 2.71 (m, 2H), 2.52 (m, 2H), 1.60 (m, 2H), 1.49 (m, 2H), 1.00 (t,  $J$  = 7.3 Hz, 3H), 0.95 (t,  $J$  = 7.3 Hz, 3H).  $^{13}\text{C}$  NMR  $\delta$  182.46, 161.72, 135.37, 128.83, 128.58, 128.21, 115.87, 104.77, 67.26, 40.77, 35.80, 22.36, 21.86, 14.54, 14.32. LRMS:  $m/z$  272.1 ( $\text{M}+1$ ). IR (neat) 2223, 1729  $\text{cm}^{-1}$ . Anal. Calcd for  $\text{C}_{17}\text{H}_{21}\text{NO}_2$ : C, 75.25; H, 7.80; N, 5.16. Found: C, 75.44; H, 7.80; N, 5.22.

##### B. 1-Cyano-2,2-dipropyl-cyclopropanecarboxylic acid benzyl ester

To a solution of 2-cyano-3-propyl-hex-2-enoic acid benzyl ester (0.91g, 3.35 mmol) in 50 mL acetonitrile was added nitromethane (0.91 mL, 16.77 mmol), followed by DBU (0.50 mL, 3.35 mmol) resulting in an orange solution. The reaction was stirred at room temperature for 16 hours, then partitioned between  $\text{Et}_2\text{O}$  and 1N HCl (aq). The phases were separated, and the organic

phase washed with brine, dried (MgSO<sub>4</sub>), and concentrated. Flash chromatography of the residue (5→10% EtOAc/hexanes) afforded 0.71g (81%) of 1-cyano-2,2-dipropyl-cyclopropanecarboxylic acid benzyl ester as a pale yellow oil. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.35 (m, 5H), 5.21 (dd, *J* = 18.3, 12.4 Hz, 2H), 1.79 (d, *J* = 5.1 Hz, 1H), 1.74 (m, 1H), 1.52 (m, 3H), 1.43 (d, *J* = 5.1 Hz, 1H), 1.36 (m, 3H), 1.04 (m, 1H), 0.95 (t, *J* = 7.1 Hz, 3H), 0.73 (t, *J* = 7.1 Hz, 3H). <sup>13</sup>C NMR δ 166.40, 135.22, 128.81, 128.69, 128.48, 118.60, 68.23, 41.26, 36.45, 30.27, 29.76, 24.91, 19.74, 19.65, 14.22, 14.10. IR (neat) 2240, 1734 cm<sup>-1</sup>. Anal. Calcd for C<sub>18</sub>H<sub>23</sub>NO<sub>2</sub>: C, 75.76; H, 8.12; N, 4.91. Found: C, 75.38; H, 8.02; N, 4.97.

C. 1-Aminomethyl-2,2-dipropyl-cyclopropanecarboxylic acid

To a solution of 1-cyano-2,2-dipropyl-cyclopropanecarboxylic acid benzyl ester (0.35g, 1.79 mmol) in 16 mL MeOH-HCl was added platinum dioxide (PtO<sub>2</sub>) (0.035g). The mixture was hydrogenated in a Parr shaker at 48 psi for 21 hours. The mixture was filtered and concentrated. Flash chromatography of the residue on silica gel (0.25:1.25:3.5 conc. ammonium hydroxide (NH<sub>4</sub>OH) (aq):MeOH:CH<sub>2</sub>Cl<sub>2</sub>), followed by ion-exchange chromatography on a DOWEX-50WX8-100 resin provided 0.09g (18%) of 1-aminomethyl-2,2-dipropyl-cyclopropanecarboxylic acid as a colorless solid, mp 255-257 °C: <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 3.26 (d, *J* = 12.9 Hz, 1H), 3.03 (d, *J* = 12.9 Hz, 1H), 1.69 (m, 1H), 1.56 (m, 2H), 1.28-1.50 (m, 4H), 1.26 (d, *J* = 4.4 Hz, 1H), 1.17 (m, 1H), 0.93 (t, *J* = 7.3 Hz, 3H), 0.85 (t, *J* = 7.3 Hz, 3H), 0.54 (d, *J* = 4.6 Hz, 1H). LRMS: *m/z* 198.1 (M-1). Anal. Calcd for C<sub>11</sub>H<sub>21</sub>NO<sub>2</sub>: C, 66.29; H, 10.62; N, 7.03. Found: C, 66.39; H, 10.79; N, 7.05.

The following compounds were prepared according to the procedure described in Example 8 above.

**Example 9**

1-AMINOMETHYL-5-METHYL-SPIRO[2.4]HEPTANE-1-CARBOXYLIC ACID  
(DIASTEREOMERIC MIXTURE)

mp 249 °C (dec). LRMS: *m/z* 182.1 (M-1).

### Example 10

#### 1-AMINOMETHYL-2,2-DIMETHYL-CYCLOPROPANECARBOXYLIC ACID

mp 254-256 °C. <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 3.12 (s, 2H), 1.26 (d, *J* = 4.6 Hz, 1H), 1.22 (s, 3H), 1.21 (s, 3H), 0.53 (d, *J* = 4.6 Hz, 1H). LRMS: *m/z* 141.9 (M-1).

### Example 11

#### 1-AMINOMETHYL-2-(1-ETHYL-PROPYL)-CYCLOPROPANECARBOXYLIC ACID

##### A. 2-Cyano-4-ethyl-hex-2-enoic acid benzyl ester

To a mixture of 2-ethylbutyraldehyde (2.0 mL, 16.2 mmol) and benzyl cyanoacetate (2.85 g, 16.2 mmol) at 0 °C was added acetic acid (0.1 mL, 1.62 mmol), then piperidine (0.16 mL, 1.62 mmol) dropwise. The ice bath was removed, and stirring continued for 10 minutes. Additional acetic acid (0.1 mL) and piperidine (0.16 mL) were added, followed by the additional of oven-dried 4A molecular sieves such that stirring was not impeded. The mixture was stirred 1.5h, then partitioned between EtOAc and sat. NaHCO<sub>3</sub> (aq). The phases were separated, and the organic phase washed with brine, dried (MgSO<sub>4</sub>), and concentrated to provide 3.96 g (95%) of 2-cyano-4-ethyl-hex-2-enoic acid benzyl ester as a colorless oil. <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.39 (m, 6H), 5.28 (s, 2H), 2.60 (m, 1H), 1.62 (m, 2H), 1.40 (m, 2H), 0.88 (t, *J* = 7.6 Hz, 6H). <sup>13</sup>C NMR δ 168.69, 161.40, 135.01, 128.90, 128.82, 128.50, 114.11, 109.94, 68.07, 46.35, 27.30, 11.95. IR (neat) 2233, 1729 cm<sup>-1</sup>. LRMS: *m/z* 256.1 (M-1). Anal. Calcd for C<sub>16</sub>H<sub>19</sub>NO<sub>2</sub>: C, 74.68; H, 7.44; N, 5.44. Found: C, 74.75; H, 7.52; N, 5.50.

##### B. 1-Cyano-2-(1-ethyl-propyl)-cyclopropanecarboxylic acid benzyl ester

To a solution of 2-cyano-4-ethyl-hex-2-enoic acid benzyl ester (3.76 g, 14.6 mmol) in 80 mL acetonitrile was added nitromethane (3.95 mL, 73 mmol), followed by DBU (2.18 mL, 14.6 mmol) resulting in an orange solution. The reaction was heated to 60 °C for 16 hours, then cooled and partitioned between Et<sub>2</sub>O and 1N HCl (aq). The phases were separated, and the organic phase washed with brine, dried (MgSO<sub>4</sub>), and concentrated. Flash

chromatography of the residue (5→10% EtOAc/hexanes) afforded 2.63g (66%) of 1-cyano-2-(1-ethyl-propyl)-cyclopropanecarboxylic acid benzyl ester as a pale yellow oil.  $^1\text{H}$  NMR ( $\text{CDCl}_3$ )  $\delta$  7.35 (m, 5H), 5.22 (m, 2H), 1.86 (dd,  $J$  = 9.0, 4.6 Hz, 1H), 1.72 (m, 1H), 1.45-1.57 (m, 4H), 1.42 (dd,  $J$  = 8.3, 4.6 Hz, 1H), 1.14 (m, 1H), 0.93 (m, 6H).  $^{13}\text{C}$  NMR  $\delta$  168.21, 135.12, 128.88, 128.73, 128.16, 117.77, 68.25, 42.41, 36.72, 26.18, 25.97, 25.20, 19.33, 11.19, 10.84. LRMS:  $m/z$  272.1 ( $M+1$ ). IR (neat) 2245, 1734  $\text{cm}^{-1}$ . Anal. Calcd for  $\text{C}_{17}\text{H}_{21}\text{NO}_2$ : C, 75.25; H, 7.80; N, 5.16. Found: C, 75.44; H, 7.83; N, 5.22.

C. 1-Aminomethyl-2-(1-ethyl-propyl)-cyclopropanecarboxylic acid

To a solution of 1-cyano-2-(1-ethyl-propyl)-cyclopropanecarboxylic acid benzyl ester (1.76g, 6.5 mmol) in 25 mL THF was added 20% Pd/C (0.2g). The mixture was hydrogenated in a Parr shaker at 48 psi for 3 hours.  $^1\text{H}$  NMR analysis indicated the benzyl ester had been completely cleaved. The mixture was filtered and concentrated hydrochloric acid (2g) was added along with  $\text{PtO}_2$  (0.42 g) and the mixture was hydrogenated for an additional 16 hours until the nitrile was reduced. The mixture was filtered and concentrated. Flash chromatography of the residue on silica gel (0.25:1.25:3.5 conc.  $\text{NH}_4\text{OH}$  (aq): $\text{MeOH}:\text{CH}_2\text{Cl}_2$ ), followed by ion-exchange chromatography on a DOWEX-50WX8-100 resin provided 0.13g (11%) of 1-aminomethyl-2-(1-ethyl-propyl)-cyclopropanecarboxylic acid as a colorless solid, mp 255-257  $^\circ\text{C}$ :  $^1\text{H}$  NMR ( $\text{D}_2\text{O}$ )  $\delta$  3.53 (d,  $J$  = 13.2 Hz, 1H), 2.50 (d,  $J$  = 13.2 Hz, 1H), 1.30 (m, 3H), 1.08-1.23 (m, 4H), 0.74 (t,  $J$  = 7.6 Hz, 3H), 0.65 (t,  $J$  = 7.6 Hz, 3H), 0.54 (m, 1H). LRMS:  $m/z$  184.1 ( $M-1$ ). Anal. Calcd for  $\text{C}_{10}\text{H}_{19}\text{NO}_2$ : C, 64.83; H, 10.34; N, 7.56. Found: C, 64.84; H, 10.69; N, 7.44.

The title compounds of Examples 12 and 13 were prepared according to the procedure described in Example 11 above.

**Example 12**

1-AMINOMETHYL-2-ISOPROPYL-CYCLOPROPANECARBOXYLIC ACID

$^1\text{H}$  NMR ( $\text{D}_2\text{O}$ )  $\delta$  3.64 (d,  $J$  = 13.7Hz, 1H), 2.66 (d,  $J$  = 13.7 Hz, 1H), 1.36 (m, 2H), 1.08 (m, 1H), 0.86 (d,  $J$  = 6.3 Hz, 3H), 0.76 (m, 1H), 0.75 (d,  $J$  = 6.6 Hz, 3H).



### Exempl 13

#### 1-AMINOMETHYL-2-CYCLOHEXYL-CYCLOPROPANECARBOXYLIC ACID

mp 270 °C (dec). <sup>1</sup>H NMR (CD<sub>3</sub>OD) δ 3.56 (d, *J* = 12.7 Hz, 1H), 2.55 (d, *J* = 12.7 Hz, 1H), 1.59-1.81 (m, 6H), 1.38 (m, 1H), 1.10-1.25 (m, 6H), 0.49 (m, 1H). LRMS: *m/z* 198.1 (*M*+1).

### Example 14

#### 1-AMINOMETHYL-SPIRO[2.5]OCTANE-1-CARBOXYLIC ACID HYDROCHLORIDE

##### A. Cyano-cyclopentylidene-acetic acid methyl ester

To a solution of cyclopentanone (84.1 g, 1 mol) in dry benzene (100 mL) was added methyl cyanoacetate (99.1 g, 1 mol), ammonium acetate (10 g) and glacial acetic acid (20 mL). The reaction mixture was heated to reflux using Dean-Stark apparatus for 12 hours and allowed to cool to room temperature. Excess of solvents was removed in vacuo and the residue was dissolved in EtOAc (400 mL). The organic layer was washed with water, dried (Na<sub>2</sub>SO<sub>4</sub>) and evaporated to give the product as pale yellow oil. Further purification of the pale yellow oil by distillation (10 mm Hg, 140-145°C) provided cyano-cyclopentylidene-acetic acid methyl ester (130 g, 79%) as a colorless oil: <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>) δ 1.80 (m, 4H), 2.80 (t, 2H), 3.0 (t, 2H), 3.80 (s, 3H); <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>) δ 25.4, 26.9, 35.8, 38.1, 52.5, 100.7, 115.8, 162.6, 188.3.

##### B. 1-Cyano-spiro[2.4]heptane-1-carboxylic acid methyl ester

To a solution of cyano-cyclopentylidene-acetic acid methyl ester (20.8 g, 126 mmol) in acetonitrile (500 mL) was added nitromethane (34 mL, 630 mmol, 5 eq) followed by dropwise addition of 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) (18.8 mL, 126 mmol). The reaction solution turned orange upon the addition of DBU. The reaction mixture was stirred at room temperature for 16 hours. Another portion of DBU (1 mL) was added and stirred for 1 hour. The reaction mixture was partitioned between ether (1 L) and 1N HCl (400 mL) and the layers separated. The organic layer was washed with 1N HCl (2 x 300 mL), brine (2 x 200 mL), dried over sodium sulfate, filtered and

evaporated. The residue was chromatographed on a wet-packed silica gel column eluting with 4-6% ethyl acetate/hexanes. The appropriate fractions were combined and evaporated to furnish 14.0 g (62%) of 1-cyano-spiro[2.4]heptane-1-carboxylic acid methyl ester as a clear oil:  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ )  $\delta$  1.64 (d,  $J = 5.0$  Hz, 1H), 1.70-1.88 (m, 7H), 2.14 (d,  $J = 5.0$  Hz, 1H), 2.1-2.19 (m, 1H), 3.82 (s, 3H); MS (APCI)  $m/z$  180  $[\text{M}+\text{H}]^+$ .

C. 1-Aminomethyl-spiro[2.4]heptane-1-carboxylic acid methyl ester

To a solution of 1-cyano-spiro[2.4]heptane-1-carboxylic acid methyl ester (3.45 g, 19.3 mmol) in methanol (240 mL) was added  $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$  (9.16 g, 38.5 mmol) to give a deep purple colored solution. Sodium borohydride (7.30 g, 193 mmol) was added portionwise over 10 minutes with caution to control the evolution of hydrogen and the exothermic reaction that ensued to give a black solution. The reaction mixture was stirred for 30 minutes under nitrogen after the addition was completed. The reaction was quenched carefully by the addition of 0.5N HCl (1.3 L). The solution was made alkaline (pH  $\sim$  9) by the addition of concentrated ammonium hydroxide. The mixture was extracted with ethyl acetate (4 x 400 mL). The combined organic layers were dried over sodium sulfate, filtered and evaporated to afford 3.07 g (87%) of 1-aminomethyl-spiro[2.4]heptane-1-carboxylic acid methyl ester as a yellow oil:  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ )  $\delta$  0.74 (br d, 1H), 1.4-1.7 (m, 10H), 1.9 (m, 1H), 2.58 (d,  $J = 13.8$  Hz, 1H), 3.16 (d,  $J = 13.8$  Hz, 1H), 3.48 (s, 3H); MS (APCI)  $m/z$  184  $[\text{M}+\text{H}]^+$ .

D. 1-Aminomethyl-spiro[2.4]heptane-1-carboxylic acid

To a solution of 1-aminomethyl-spiro[2.4]heptane-1-carboxylic acid methyl ester (3.40 g, 18.6 mmol) was added methanol (75 mL) and  $\text{LiOH} \cdot \text{H}_2\text{O}$  (1.55 g, 37.1 mmol). The mixture was heated to reflux under nitrogen for 48 hours. The solvent was removed by evaporation under reduced pressure and the residue was dissolved in water (50 mL). With ice bath cooling, concentrated HCl ( $\sim$ 2.5 mL) was added until the pH was adjusted to 6. A white precipitate was isolated by filtration and dried under vacuum to yield 1.22 g (39%) of 1-aminomethyl-spiro[2.4]heptane-1-carboxylic acid as an off-

white solid: mp 231-235 °C (decomposition);  $^1\text{H}$  NMR (300 MHz,  $\text{D}_2\text{O}$ )  $\delta$  0.78 (d,  $J = 4.7$  Hz, 1H), 1.32 (d,  $J = 4.7$  Hz, 1H), 1.40 (m, 1H), 1.54-1.77 (m, 7 H), 2.86 (d,  $J = 13.2$  Hz, 1H), 3.43 (d,  $J = 13.2$  Hz, 1H); MS (APCI)  $m/z$  170  $[\text{M}+\text{H}]^+$ . Anal. Calcd. For  $\text{C}_9\text{H}_{15}\text{NO}_2 \cdot 1.1\text{H}_2\text{O}$ : C, 57.18; H, 9.17; N, 7.41. Found: C, 57.38; H, 8.82; N, 7.09.

E. Cyano-cyclohexylidene-acetic acid methyl ester

To a solution of cyclohexanone (84.1 g, 1 mol) in dry benzene (100 mL) was added methyl cyanoacetate (99.1 g, 1 mol), ammonium acetate (10 g) and glacial acetic acid (20 mL). The reaction mixture was heated to reflux using Dean-Stark apparatus for 12 hours and allowed to cool to room temperature. Excess of solvents was removed in vacuo and the residue was dissolved in EtOAc (400 mL). The organic layer was washed with water, dried over sodium sulfate and evaporated to give cyano-cyclohexylidene-acetic acid methyl ester as pale yellow oil. Further purification of the pale yellow oil by distillation (10 mm Hg, 150-155 °C) gave product the title compound (110 g, 61%) as a colorless oil:  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ )  $\delta$  1.70-1.85 (m, 6H), 2.70 (t, 2H), 3.00 (t, 2H), 3.80 (s, 3H);  $^{13}\text{C}$  NMR (75 MHz,  $\text{CDCl}_3$ )  $\delta$  25.9, 28.6, 28.9, 31.9, 37.2, 52.8, 101.9, 115.8, 162.7, 180.8.

F. 1-Cyano-spiro[2.5]octane-1-carboxylic acid methyl ester

To a solution of cyano-cyclohexylidene-acetic acid methyl ester (20.0 g, 112 mmol) in acetonitrile (400 mL) was added nitromethane (30 mL, 558 mmol) followed by dropwise addition of DBU (16.9 mL, 113 mmol) over five minutes. The solution went from clear to orange and was stirred at room temperature for 5.5 hours. The solution was diluted with ether (1 L), washed with 1N HCl (2 x 250 mL) and then brine (2 x 250 mL). The organic layer was dried over sodium sulfate, filtered and evaporated. The residue was chromatographed on a wet-packed silica gel column (6.5 x 40 cm) eluting with 95:5 hexanes/ethyl acetate. The appropriate fractions were combined and evaporated to give 18.6 g (86%) of 1-cyano-spiro[2.5]octane-1-carboxylic acid methyl ester as a clear oil:  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ )  $\delta$  1.35 (m, 1H), 1.49 (d,  $J = 5.0$  Hz, 1H), 1.5-1.75 (m, 9H), 1.82 (d,  $J = 5.0$  Hz, 1H), 3.83 (s, 3H).

G. 1-(*tert*-Butoxycarbonylamino-methyl)-spiro[2.5]octane-1-carboxylic acid methyl ester

To a solution of 1-cyano-spiro[2.5]octane-1-carboxylic acid methyl ester (18.6 g, 96.2 mmol) in methanol (480 mL) was added  $\text{CoCl}_2 \cdot \text{H}_2\text{O}$  (22.8 g, 96.2 mmol) to give a deep purple color. Sodium borohydride (14.5 g, 385 mmol) was added portionwise over 10 minutes with ice bath cooling to give a black colored solution. After 40 minutes, the reaction was quenched carefully with 2N HCl. The pH was adjusted to 9 with 2N NaOH and the solution was extracted with  $\text{CH}_2\text{Cl}_2$  (4 times). To the combined organic layer was added saturated potassium carbonate solution and di-*tert*-butyldicarbonate (26.2 g, 120 mmol). After 1 hour, the layers were separated. The organic layer was dried over sodium sulfate, filtered and evaporated to give 35.7 g (>100%) of 1-(*tert*-butoxycarbonylamino-methyl)-spiro[2.5]octane-1-carboxylic acid methyl ester as an off-white solid. The material was used without further purification in the next step.

H. 1-(*tert*-Butoxycarbonylamino-methyl)-spiro[2.5]octane-1-carboxylic acid

To a solution of crude 1-(*tert*-butoxycarbonylamino-methyl)-spiro[2.5]octane-1-carboxylic acid methyl ester (35.0 g, ~96.2 mmol) was added  $\text{LiOH} \cdot \text{H}_2\text{O}$  (12.3 g, 294 mmol) followed by the addition of water (75 mL). The mixture was heated to reflux. After 48 hours, an additional portion of  $\text{LiOH} \cdot \text{H}_2\text{O}$  (6.15 g, 146 mmol) was added and refluxed for an additional 24 hours. The solvent was removed under reduced vacuum. The residue was partitioned between water and ether. The aqueous layer was acidified to pH 2-3 with aqueous HCl with ice bath cooling with a layer of  $\text{CH}_2\text{Cl}_2$  present. The layers were separated and the aqueous layer was extracted with  $\text{CH}_2\text{Cl}_2$  (3 times). The combined organic layers were dried over sodium sulfate, filtered and evaporated to give 17.0 g (63%, 2 steps) of 1-(*tert*-butoxycarbonylamino-methyl)-spiro[2.5]octane-1-carboxylic acid an off-white solid.

I. 1-Aminomethyl-spiro[2.5]octane-1-carboxylic acid hydrochloride

To a solution of 1-(*tert*-butoxycarbonylamino-methyl)-spiro[2.5]octane-1-carboxylic acid (200 mg, 0.706 mmol) in 1,4-dioxane (3 mL) was added 4N HCl in 1,4-dioxane (3 mL). The reaction was stirred for 18 hours at room temperature. Ether (20 mL) was added and the precipitate was isolated by vacuum filtration. The solid was dried in a vacuum oven at 48 °C to give 133 mg (86%) of 1-aminomethyl-spiro[2.5]octane-1-carboxylic acid hydrochloride as a white solid: mp 240-242 °C; <sup>1</sup>H NMR (300 MHz, D<sub>2</sub>O) δ 0.92 (d, *J* = 5.2 Hz, 1H), 1.40 (d, *J* = 5.2 Hz, 1H), 1.4-1.6 (m, 10H), 3.12 (d, *J* = 14.0 Hz, 1H), 3.61 (d, *J* = 14.0 Hz, 1H); MS (APCI) *m/z* 184 [M+H]<sup>+</sup>. Anal. Calcd. For C<sub>10</sub>H<sub>17</sub>NO<sub>2</sub>·HCl: C, 54.67; H, 8.26; N, 6.38; Cl, 16.14. Found: C, 54.91; H, 8.36; N, 6.25; Cl, 15.99.

### Example 15

#### 1-AMINOMETHYL-2-ISOBUTYL-CYCLOPROPANECARBOXYLIC ACID HYDROCHLORIDE

##### A. 2-Cyano-4-methyl-pent-2-enoic acid methyl ester

To a solution of isobutyraldehyde (18.2 mL, 200 mmol) in dry benzene (20 mL) was added methyl cyanoacetate (18 mL, 200 mmol), ammonium acetate (2 g) and glacial acetic acid (4 mL). The reaction mixture was stirred at 60 °C for 30 minutes and allowed to cool to room temperature. Excess of solvents was removed in vacuo and the residue was dissolved in EtOAc (200 mL). The organic layer was washed with water, dried over sodium sulfate and evaporated to give 2-cyano-4-methyl-pent-2-enoic acid methyl ester as pale yellow oil. Further purification of the pale yellow oil by distillation (7 mm Hg) gave product **2** (27.4 g, 56%) as colorless oil: <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>) δ 1.16 (d, *J* = 6.6 Hz, 6H), 2.96-3.04 (m, 1H), 3.87 (s, 3H), 7.47 (d, *J* = 10.5 Hz, 1H).

##### B. 1-Cyano-2-isopropyl-cyclopropanecarboxylic acid methyl ester

To a solution of 2-cyano-4-methyl-pent-2-enoic acid methyl ester (10.5 g, 68.3 mmol) in dry acetonitrile (60 mL) was added nitromethane (5.5 mL, 103 mmol) and a portionwise addition of alumina-supported potassium fluoride (40% wt, 22 g). The reaction mixture was stirred under reflux for 2 hours and cooled to room temperature. The solid was removed by filtration

through a short pad of celite and washed with acetonitrile. Excess of solvent was removed in vacuo and the residue was re-dissolved in ether. The ether layer was washed with water, brine, dried ( $\text{Na}_2\text{SO}_4$ ) and concentrated in vacuo. The crude product was purified by flash column chromatography using hexanes/EtOAc (8:2) as an eluent to afford 1-cyano-2-isopropyl-cyclopropanecarboxylic acid methyl ester (7.7 g, 68%) as colorless oil:  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ )  $\delta$  1.13 (t,  $J = 7.2$  Hz, 6H), 1.39-1.45 (m, 2H), 1.65-1.74 (m, 1H), 1.81 (dd,  $J = 4.4, 8.9$  Hz, 1H), 3.81 (s, 3H);  $^{13}\text{C}$  NMR (75 MHz,  $\text{CDCl}_3$ )  $\delta$  19.6, 21.8, 21.9, 25.3, 31.2, 39.3, 53.7, 117.6, 168.7.

C. 1-(*tert*-Butoxycarbonylamino-methyl)-2-isopropyl-cyclopropanecarboxylic acid methyl ester

To a solution of 1-cyano-2-isopropyl-cyclopropanecarboxylic acid methyl ester (7.7 g, 46.1 mmol) and cobaltous chloride hexahydrate (21.9 g, 92.2 mmol) in MeOH (560 mL) was added  $\text{NaBH}_4$  (17.4 g, 461 mmol) in portions. The black precipitate formed was stirred for 1 hour at room temperature and was quenched with 0.5N HCl (200 mL). After the black precipitate dissolved, excess of solvent was removed and aqueous layer was made alkaline by addition of 2N NaOH. The alkaline solution was added slowly to a solution of di-*tert*-butyldicarbonate (20.1 g, 92.2 mmol) in dichloromethane (400 mL). The reaction mixture was stirred at room temperature overnight and the organic layer was separated and washed with brine and dried ( $\text{Na}_2\text{SO}_4$ ). Evaporation of excess of solvent followed by purification of the residue by column chromatography using hexanes/EtOAc (9:1) as an eluent furnished 1-(*tert*-butoxycarbonylamino-methyl)-2-isopropyl-cyclopropanecarboxylic acid methyl ester (10.9 g, 88%) as colorless oil:  $^1\text{H}$  NMR (300 MHz,  $\text{CD}_3\text{OD}$ )  $\delta$  0.76 (m, 1H), 0.97 (d,  $J = 6.3$  Hz, 3H), 1.05 (d,  $J = 6.3$  Hz, 3H), 1.26-1.31 (m, 3H), 1.43 (s, 9H), 3.23 (d,  $J = 14.3$  Hz, 1H), 3.57 (d,  $J = 14.3$  Hz, 1H), 3.69 (s, 3H);  $^{13}\text{C}$  NMR (75 MHz,  $\text{CD}_3\text{OD}$ )  $\delta$  20.5, 23.4, 23.6, 29.2, 38.1, 41.1, 53.0, 80.5, 158.5, 177.1; MS (APCI)  $m/z$  172 [ $\text{M}+\text{H}-100(\text{Boc})$ ] $^+$ .

D. 1-(*tert*-Butoxycarbonylamino-methyl)-2-isopropyl-cyclopropanecarboxylic acid

To a solution of 1-(*tert*-butoxycarbonylamino-methyl)-2-isopropyl-cyclopropanecarboxylic acid methyl ester (10.9 g, 40.2 mmol) in MeOH (320 mL) was added a solution of LiOH (4.2 g, 100 mmol) in water (98 mL). The reaction mixture was heated to reflux for 3 hours and cooled to room temperature. Excess of solvent was removed and the residue was dissolved in water (100 mL). The aqueous solution was washed with ether, acidified to pH = 3 with 2N HCl and extracted with EtOAc (2 x 150 mL). The combined organic phase was washed with brine, dried (Na<sub>2</sub>SO<sub>4</sub>) and evaporation of the solvent provided 1-(*tert*-butoxycarbonylamino-methyl)-2-isopropyl-cyclopropanecarboxylic acid (9.0 g, 87%) as a colorless oil: <sup>1</sup>H NMR (300 MHz, CD<sub>3</sub>OD) δ 0.72 (m, 1H), 0.99 (d, *J* = 6.2 Hz, 3H), 1.06 (d, *J* = 6.2 Hz, 3H), 1.28-1.36 (m, 3H), 1.42 (s, 9H), 3.23 (d, *J* = 14.3 Hz, 1H), 3.54 (d, *J* = 14.3 Hz, 1H); <sup>13</sup>C NMR (75 MHz, CD<sub>3</sub>OD) δ 20.0, 23.0, 23.3, 28.8, 30.2, 37.6, 40.8, 80.2, 158.1, 178.5; MS (APCI) *m/z* 258 [M+H]<sup>+</sup>.

E. 1-Aminomethyl-2-isopropyl-cyclopropanecarboxylic acid hydrochloride

To a solution of 1-(*tert*-butoxycarbonylamino-methyl)-2-isopropyl-cyclopropanecarboxylic acid (2.05 g, 8.0 mmol) in dry 1,4-dioxane (40 mL) was added 4N HCl (40 mL, in 1,4-dioxane). The reaction mixture was stirred at room temperature overnight and ether was added (100 mL). The white solid was collected and dried to give 1-aminomethyl -2-isopropyl-cyclopropanecarboxylic acid hydrochloride (1.35 g, 88%): mp: 245-246 °C; <sup>1</sup>H NMR (300 MHz, D<sub>2</sub>O) δ 0.94 (d, *J* = 6.5 Hz, 3H), 0.96 (m, 1H), 1.05 (d, *J* = 6.4 Hz, 3H), 1.23-1.31 (m, 1H), 1.49-1.59 (m, 2H), 2.85 (d, *J* = 13.7 Hz, 1H), 3.83 (d, *J* = 13.7 Hz, 1H); <sup>13</sup>C NMR (75 MHz, D<sub>2</sub>O) δ 22.3, 23.9, 27.8, 30.8, 39.6, 41.7, 179.6; MS (APCI) *m/z* 158 [M+H]<sup>+</sup>. Anal. Calcd. For C<sub>8</sub>H<sub>15</sub>NO<sub>2</sub>-HCl: C, 49.61; H, 8.33; N, 7.23; Cl, 18.31. Found: C, 49.76; H, 8.44; N, 7.11; Cl, 18.48.

F. 2-Cyano-5 methyl-hex-2-enoic acid methyl ester

To a solution of isovaleraldehyde (86.1 g, 1 mol) in dry benzene (100 mL) was added methyl cyanoacetate 2 (99.1 g, 1 mol), ammonium acetate (10 g) and glacial acetic acid (20 mL). The reaction mixture was stirred at 0 °C for 1 hour and allowed to cool to room temperature. Excess of solvents was removed in vacuo and the residue was dissolved in EtOAc (400 mL). The organic layer was washed with water, dried over sodium sulfate and evaporated to give the product as pale yellow oil. Further purification of the pale yellow oil by distillation (10 mm Hg) gave 100 g (60%) of 2-cyano-5 methyl-hex-2-enoic acid methyl ester as a colorless oil: <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>) δ 1.00 (d, *J* = 6.7 Hz, 6H), 1.91 (m, 1H), 2.47 (dd, *J* = 7.9, 6.8 Hz, 2H), 3.89 (s, 3H), 7.69 (t, *J* = 8.0 Hz, 1H).

G. 1-Cyano-2-isobutyl-cyclopropanecarboxylic acid methyl ester

To a solution of 2-cyano-5 methyl-hex-2-enoic acid methyl ester (20.2 g, 121 mmol) in dry acetonitrile (110 mL) was added nitromethane (9.8 mL, 181 mmol) and a portionwise addition of alumina-supported potassium fluoride (40% wt, 39.3 g). The reaction mixture was stirred under reflux for 2 hours and cooled to room temperature. The solid was removed by filtration through a short pad of celite and washed with acetonitrile. Excess of solvent was removed in vacuo and the residue was re-dissolved in ether. The ether layer was washed with water, brine, dried (Na<sub>2</sub>SO<sub>4</sub>) and concentrated in vacuo. The crude product was purified by flash column chromatography using hexanes/EtOAc (8:2) as an eluent to give 15 g (69%) of 1-cyano-2-isobutyl-cyclopropanecarboxylic acid methyl ester as colorless oil: <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>) δ 0.98 (d, *J* = 2.9 Hz, 3H), 1.00 (d, *J* = 3.0 Hz, 3H), 1.35-1.42 (m, 2H), 1.65 (m, 1H), 1.79-1.94 (m, 3H), 3.81 (s, 3H); <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>) δ 19.3, 22.3, 22.4, 25.5, 27.9, 30.1, 39.0, 53.4, 117.3, 168.5.

H. 1-(*tert*-Butoxycarbonylamino-methyl)-2-isobutyl-cyclopropanecarboxylic acid methyl ester

To a solution of 1-cyano-2-isobutyl-cyclopropanecarboxylic acid methyl ester (13.0 g, 71.8 mmol) and cobaltous chloride hexahydrate (34.2 g, 144 mmol) in MeOH (800 mL) was added NaBH<sub>4</sub> (27.2 g, 718 mmol) in portions.



The black precipitate formed was stirred for 1 hour at room temperature and was quenched with 0.5N HCl (400 mL). After the black precipitate dissolved, excess of solvent was removed and aqueous layer was made alkaline by addition of 2N NaOH. The alkaline solution was added slowly to a solution of di-*tert*-butyldicarbonate (31.4 g, 144 mmol) in dichloromethane (600 mL). The reaction mixture was stirred at room temperature overnight and the organic layer was separated and washed with brine and dried (Na<sub>2</sub>SO<sub>4</sub>). Evaporation of excess of solvent followed by purification of the residue by column chromatography using hexanes/EtOAc (9:1) as an eluent gave 16 g (78%) of 1-(*tert*-butoxycarbonylamino-methyl)-2-isobutyl-cyclopropanecarboxylic acid methyl ester as a colorless oil: <sup>1</sup>H NMR (300 MHz, CDCl<sub>3</sub>) δ 0.75 (m, 1H), 0.93 (t, *J* = 6.5 Hz, 6H), 1.20-1.28 (m, 1H), 1.37 (dd, *J* = 3.8, 8.5 Hz, 1H), 1.44 (s, 9H), 1.51-1.58 (m, 2H), 1.64-1.70 (m, 1H), 3.33-3.46 (m, 2H), 3.67 (s, 3H), 5.27 (m, 1H); <sup>13</sup>C NMR (75 MHz, CDCl<sub>3</sub>) δ 21.1, 22.4, 22.9, 26.7, 28.6, 28.7, 28.9, 37.8, 40.2, 52.1, 79.1, 156.1, 175.8; MS (APCI) *m/z* 186 [M+H-100(Boc)]<sup>+</sup>.

I. 1-(*tert*-Butoxycarbonylamino-methyl)-2-isobutyl-cyclopropanecarboxylic acid

To a solution of 1-(*tert*-butoxycarbonylamino-methyl)-2-isobutyl-cyclopropanecarboxylic acid methyl ester (9.1 g, 31.9 mmol) in MeOH (260 mL) was added a solution of LiOH (3.34 g, 79.7 mmol) in water (80 mL). The reaction mixture was heated to reflux for 3 hours and cooled to room temperature. Excess of solvent was removed and the residue was dissolved in water (100 mL). The aqueous solution was washed with ether, acidified to pH = 3 with 2N HCl and extracted with EtOAc (2 x 150 mL). The combined organic phase was washed with brine, dried (Na<sub>2</sub>SO<sub>4</sub>) and evaporation of the solvent gave 8.4 g (97%) of 1-(*tert*-butoxycarbonylamino-methyl)-2-isobutyl-cyclopropanecarboxylic acid as a colorless oil: <sup>1</sup>H NMR (300 MHz, CD<sub>3</sub>OD) δ 0.71 (dd, *J* = 4.0, 6.4 Hz, 1H), 0.95 (t, *J* = 6.4 Hz, 6H), 1.35 (m, 1H), 1.43 (s, 1H), 1.49-1.55 (m, 1H), 1.64-1.69 (m, 2H), 3.23 (d, *J* = 14.2 Hz, 1H), 3.40 (d, *J* = 14.2 Hz, 1H).

J. 1-Aminomethyl-2-isobutyl-cyclopropanecarboxylic acid hydrochloride

To a solution of 1-(*tert*-butoxycarbonylamino-methyl)-2-isobutyl-cyclopropanecarboxylic acid (2.8 g, 10.3 mmol) in dry 1,4-dioxane (60 mL) was added 4N HCl (40 mL, in 1,4-dioxane). The reaction mixture was stirred at room temperature overnight and ether was added (100 mL). The white solid was collected and dried to give 1.6 g (76%) of 1-aminomethyl-2-isobutyl-cyclopropanecarboxylic acid hydrochloride: mp: 254-255 °C; <sup>1</sup>H NMR (300 MHz, D<sub>2</sub>O) δ 0.95 (t, *J* = 6.2 Hz, 6H), 0.96 (m, 1H), 1.21-1.28 (m, 1H), 1.51-1.80 (m, 4H), 3.06 (d, *J* = 13.8 Hz, 1H), 3.58 (d, *J* = 13.8 Hz, 1H); <sup>13</sup>C NMR (75 MHz, D<sub>2</sub>O) δ 21.7, 21.9, 22.2, 25.3, 28.1, 28.6, 37.1, 40.2, 178.1; MS (APCI) *m/z* 172 [M+H]<sup>+</sup>. Anal. Calcd. For C<sub>9</sub>H<sub>17</sub>NO<sub>2</sub>-HCl: C, 52.05; H, 8.74; N, 6.74. Found: C, 52.10; H, 8.73; N, 6.67.